

ASTRONOMICAL DATING OF BABYLON I AND UR III

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We undertake a comprehensive effort to establish the absolute chronology of the First Dynasty of Babylon and of Ur III by reexamining the Venus Tablet data and by cross-checking with extensive contemporary month-length data. The presently available evidence heavily favors the Long Chronology, with Ammisaduqa year 1 beginning in -1701 = 1702 B.C.; the most likely beginning for Amarsin year 1 is -2093.

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1. Introduction

The only items known to us that relate historical dates of the first half of the second and of the late third millennium B.C. to astronomical events are:

- (1) Some Venus observations from the time of Ammisaduqa;
 - (2) Some lunar eclipse omina;
 - (3) Month-lengths as recorded in contemporary economic-administrative texts.
- Both (1) and (2) are contained in tablets of the astrological series *Enuma Anu Enlil*, and are available only in late and possibly corrupt versions. Clearly, being contemporary, the month-lengths (3) should provide the most reliable data for astronomical dating purposes.

Perhaps also some cultic offerings to planetary gods (principally Inanna-Ishtar-Venus) might be linked to planetary phenomena, and if so, they might become a very important second source of contemporary astronomical information (cf. Falkenstein (1965), p.52; Sauren (1970), with a very critical review by Hunger (1973/74)).

The astronomical dating problem now consists in the identification of all dates lying inside the historically acceptable range that are compatible with astronomy. The task is largely a statistical one: we must assess the accuracy of the observations and judge the quality of the agreement between calculations and observations, and if there are several compatible solutions, we must assess the relative strength of evidence favoring each particular solution.

The last comprehensive attempt to fix Old Babylonian chronology by astronomical means has been that by Langdon, Fotheringham and Schoch (1928), in their book *The Venus Tablets of Ammisaduqa*, henceforth cited LFS.

In the time since, the historically admissible range of solutions has been shifted several centuries; there has been a new edition of the Venus Tablet by Reiner and Pingree, *The Venus Tablet of Ammisaduqa*, Bibliotheca Mesopotamica Vol. 2,1 (1975), henceforth cited RP; we have many more attested intercalary months and month-lengths; and last, but not least, computers have taken out much of the drudgery of extensive astronomical calculations.

Aided by hindsight, we can identify the principal weak spots of LFS as follows. First, lacking computers, Fotheringham had to ignore most of the statistical aspects (e.g. questions about the accuracy of the observations and of the mathematical models used for calculating visibility conditions). Therefore, as already Otto Neugebauer (1929) had pointed out, it was not clear whether the good agreement LFS had obtained for the month-lengths with their 'Solution II' was any better than the best agreement to be expected among five randomly picked wrong chronologies. Second, and even worse, it now turns out that so many of the intercalations used by LFS are questionable and possibly wrong that their comparison of observed and calculated month-lengths is almost meaningless.

In spite of this criticism, the approach used by LFS is sound, and it appears worthwhile to undertake a new and better equipped attack along similar lines.

In view of the low trustworthiness of the Venus data, one would prefer to work with the contemporary month-lengths alone, but unfortunately, the presently available material does not suffice to pick a unique date from more than a few dozen alternatives -- the true chronology will not stick out if there are too many possibilities to choose from. So we adopt the following strategy that

plays one data set against the other and thus allows us to cross-check both:

- First, narrow the choices down to those compatible with the Venus data.
- Then check the Venus chronologies against the month-length data from Ammisaduqa's reign, and hopefully narrow the choices down to one.
- Check with month-lengths from segments of consecutive years with reasonably complete intercalations (the late years of Ammiditana, the late years of Hammurapi, and the early years of Samsuiluna).
- The Ur III chronology is fixed within about 10 years relative to Babylon I. Check and fix more precisely with the aid of the month-lengths.
- Finally, check also the eclipse material.

This strategy turned out to be reasonably successful, and our findings can be summarized as follows.

The so-called Long Chronology (Ammisaduqa year 1 = -1701 = 1702 B.C.*) fits well, both with regard to the Venus and the month-length data from Ammisaduqa's and Ammiditana's reign; the quality of the fit is even better than that obtained for reliably dated Late Babylonian control material. The Middle and Short Chronologies (i.e. -1645, -1637, -1581) agree so poorly that they must be ruled out. Among the 20 Venus chronologies investigated (ranging from Ammisaduqa year 1 = -1976 to -1362), -1701 gives the best fit. There is one other astronomically feasible choice, the 'supershort' chronology -1517, but the fit is poorer, so that the odds are about 15 to 1 in favor of -1701.

Reckoning backwards, we obtain that Hammurapi reigned from 1848 B.C. to 1806 B.C.. The Hammurapi-Samsuiluna month-length evidence is not conclusive, but it also favors the Long Chronology.

A statistical analysis shows that the agreement of the -1701 solution not only is the best one, but that it is also significantly better than what we would expect for the best among a certain number of randomly chosen wrong chronologies. The significance level depends on how wide we choose the admissible historical range and is of the order of 1% to 5%. This gives an *a posteriori* vindication of the validity of the Venus Tablet data – if the set of chronologies selected on the basis of the Venus data had not contained the correct one, we should not have obtained such a good agreement.

The Ur III data also favor the long chronology: between -2213 and -1890, the best fit for Amarsin year 1 is -2093, while reckoning back from the long chronology gives -2100 plus or minus a few years. There is no good match for the supershort chronology.

Among the authors, specific responsibilities were distributed as follows. Neo- and Late Babylonian data: Sachs; OB data: Stol; Ur III data: Whiting; data analysis: Huber. Leichty, Walker and van Driel contributed a substantial amount of NB and OB data; Walker also collated many British Museum texts. The investigation profited greatly from discussions and correspondence with many colleagues. Special thanks are due to Claus Wilcke, who carefully read an early draft and offered many helpful suggestions. The data analysis on the computer was in part supported by NSF Grant MCS-79-08685 and ONR Contract N00014-79-C-0512.

* There is a one year difference between the astronomical and the historical year count (there is no year 0 in the historical numbering, 1 B.C. is followed by 1 A.D.).

2. Astronomical theory and calculations

The calculations were based throughout on the theories and parameters used in P.V. Neugebauer's *Astronomische Chronologie* (cited PVN) and in Tuckerman's (1962, 1964) and Goldstine's (1973) tables. The computer programs were written by Huber, originally for a CDC-6500, and later adapted to a VAX-11/780.

The principal difficulty and challenge of historical astronomy resides in our insufficient knowledge of the so-called secular terms. They reflect the changes in the rotation of the earth and in the motion of the moon caused by tidal friction (and perhaps some other causes). The effects are sizeable: if we were to use the present rate of rotation for our calculations, instead of taking the changes into account, the slowing down of the earth's rotation would, by the middle of the first millennium B.C., lead to a clocktime difference of about six hours between the actual and the calculated time of day. Unfortunately, the changes are somewhat irregular, and not known with high accuracy.

The most recent treatment of the problem of the secular terms is Paul Muller's thesis (1975). Muller's estimated standard errors of his estimates of the secular terms in the rotation of the earth correspond to a clocktime error of ± 0.9 hours in the year -2100, and the errors in the lunar longitude correspond to $\pm 0.5^\circ$ (which arc is traveled by the moon in 0.9 hours). These errors are correlated in such a way that they partially cancel each other when lunar phenomena are concerned (the main reason for this is that these secular terms were estimated from lunisolar phenomena, namely historical solar eclipses). Therefore, I roughly estimate that the total, combined error should lie below the equivalent of 0.1 days or 1.3° in lunar longitude for the year -2100. By abuse of language, we shall in the following refer to the combined effects of the errors in the secular terms simply as the 'clocktime error'.

Despite the somewhat antiquated astronomical theories, the elements used by PVN are reputed to be very nearly the best possible ones, so the above estimate for the magnitude of the clocktime error should apply also to them. Indeed, if I understand Muller's corrections properly, then the mean longitudes for the year -2100 differ by -0.24° (moon) and -0.07° (sun), when they are calculated according to PVN-Tuckerman or Muller, respectively. This translates into a clocktime difference of about 20 minutes.

The Venus theory of PVN-Tuckerman is quite accurate; according to Stephenson and Houlden (1981), by the year -600 the maximum error in geocentric longitude is only about 0.05° . If we assume that the error increases quadratically with time, it still is only about 0.1° by -1700, which is negligible for our purposes. Moreover, Venus phenomena are quite insensitive to clocktime errors -- first and last visibility observations are affected by observational errors of one day or more, and any clocktime error smaller than 0.5 days simply is too small to become noticeable with the kind of OB observations we have.

Month-lengths on the other hand are quite sensitive to clocktime errors. Under ideal weather conditions and zero clocktime errors, the computed and the observed first visibility coincide in about 95% of the cases (cf. Section 5.2), and the computed and the observed month-lengths thus agree in about 90% of the cases. A rough calculation shows that a clocktime error of 0.1 days under otherwise ideal conditions would raise the probability of missing the observed crescent from about 5% to about 10%, and the probability of missing the month-length from 10% to about 20%. A clocktime error twice as big (0.2 days) would

raise the corresponding probabilities to about 20% and 36% respectively, and would probably render futile any attempt at astronomical dating with the less-than-ideal month-lengths recorded in non-astronomical texts.

Checking the Venus chronologies against the month-length data thus may also help to confirm whether calculated month-lengths are sufficiently accurate so that they can be used for dating purposes in the early second millennium B.C.

3. The calendar

The Babylonian day began at sunset, and, at least in principle, the month began with the first visibility of the lunar crescent after the new moon.

Under ideal weather conditions, the intervals between two first sightings of the crescent vary irregularly between 29, 30 and occasionally 31 days. According to calculations for the latitude of Babylon, among 1000 months there will be about 471 intervals of 29 days, 528 of 30 days and 1 of 31 days.

It is not entirely clear how the Babylonians dealt with sightings delayed by poor weather, and they need not have done it in the same way at different places and in different times.

The evidence available so far indicates that each month had at most 30 days, and that the 30th day could be cut short by the appearance of the moon. Thus, day 30 sometimes would run its full course from sunset to sunset, and sometimes it would last only about an hour, from sunset to the appearance of the lunar crescent, upon which event the first day of the next month would begin. The technical terms in Akkadian are *šullumum* and *turrum* respectively: the Moongod either 'completes' the day, or he 'turns it back'. The interpretations of these technical terms in AHW (p.1145 and p.1334) are not entirely correct. As far as we know, day 30 would always be followed by day 1; the few apparent attestations of a 31st day seem to be misreadings (of 30-lá-1, i.e. 29, or the like).

In accordance with this, the Late Babylonian astronomical texts consistently indicate the month-length by stating whether the moon became visible on 'day 30' or on 'day 1'. These same texts systematically, and often tacitly, substitute very accurate predictions when crescent observations had been missed because of poor weather.

Earlier times would not have the astronomical know-how to make accurate predictions (mathematical astronomy was invented only about 500 B.C.). A Neo-Assyrian letter contains the interesting statement: 'When I first observed the crescent of the moon on the 30th day, it was already high, too high to be the crescent of the 30th. Its position was like that of the 2nd day. So, if it suits the king, my lord, the king should wait for the report of Assur before fixing the date.' (Parpola, LAS No. 119). Presumably, the situation behind this letter is that a month earlier one had missed a crescent observation because of poor weather and had started the month a day late. Because of this, the moon now was very high when it became visible on day 30, and the author of the letter suspects that it should have been visible already on the day before, if the weather had not been bad again. When the letter was written, day 1 had already begun, and since the report from Assur would need some time to arrive, 'fixing' the date presumably means that the king would decree to skip a date early in the month and have, say, day 3 follow immediately upon day 1.

There are reports of unusually early appearances of the moon, for example Thompson RMA No. 58 mentions an appearance on the 28th day. Presumably, such an early appearance would automatically and immediately turn around the date to day 1 of the next month, but it is also possible that one would allow the month to complete the 29th day.

There can be no doubt that in Neo- and Late Babylonian times the day began at sunset. But there may have been regional differences. For example, the Neo-Assyrian letter LAS No. 1 seems to exploit a difference between the

astrological beginning of the day (at sunset) and the civil beginning (at a later point, say midnight); however, as Parpola (personal communication) points out, this interpretation hinges on the reading of the slightly damaged number 15 in Rev. line 18.

The Babylonian year began somewhere near spring equinox. Fotheringham (LFS, p.69ff.) argued on the basis of contracts for the delivery of dates and of barley, mostly from the reign of Hammurapi, that his Solution II (Ammissaduqa year 1 = -1920) agreed best with the seasons. We find it convenient to characterize the beginning of the year by the longitude of sun and moon at the New Year syzygy* (the new moon immediately preceding Nisan 1). For Fotheringham's Solution II, the Ammissaduqa New Year syzygy longitudes fluctuate around a median value of 18° , and accordingly, the OB year would on the average begin about two weeks after spring equinox.

But this argument is precarious. In particular, it assumes that there have been no climatic shifts between OB and present times, and that the average beginning of the year stayed the same between Hammurapi and Ammissaduqa.

It is evident from the very irregular pattern of intercalations that there must have been large fluctuations in the beginning of the year. We note that if a New Year syzygy happens to fall at 0° (i.e. at equinox), then the syzygy 12 or 13 months later falls at 350° or 18° , that is, about 10 days before, or 18 days after the spring equinox, respectively. Expressed differently, an ordinary year decreases the longitude by 10° , an intercalary year increases it by 18° . In OB times, two consecutive intercalary years are no rarity, and there is at least one quadruplet of intercalary years (namely Hammurapi years 32, 33, 34 and 35, see the Appendix, Section 2). Ammissaduqa's reign contains runs of 4 and of 5 consecutive regular years (namely years 6 to 9, and 14 to 18 respectively). In other words, in Hammurapi's reign the beginning of the year once was moved by $4 \times 18^\circ = 72^\circ$, or about 2.5 months, and in Ammissaduqa's time, it once was allowed to lapse by $5 \times 10^\circ \approx 52^\circ$.

Unless we either have *complete* lists of intercalations, or are able to date several reigns absolutely by astronomical means, we have no way of knowing even whether the aimed-for beginning of the year stayed the same from one king to the next. An investigation of the beginning of the year in Neo- and Late Babylonian times proves instructive; the principal reference and source is Parker and Dubberstein, *Babylonian Chronology*, 3rd edition, Brown University Press (1956), henceforth cited PD³, complemented by Goldstine's tables.

In the first part of the timespan in question (-747 to -625), the intercalations are incompletely known, but the eclipse texts in LBAT (A. Sachs, *Late Babylonian Astronomical and Related Texts*, Brown University Press (1955)), # 1413 to # 1417, allow us to fix the beginning of 14 years. Attested intercalations are indicated by the letters A or U, as in PD³.

* *Syzygy* is a collective term for new and full moons. More precisely, at the new moon syzygy, the moon has the same longitude as the sun, at the full moon syzygy, the longitudes differ by 180° . Longitudes are counted in the ecliptic, that is in the great circle traveled by the sun, from the vernal equinox (0°) to the summer solstice (90°), the autumn equinox (180°) and the winter solstice (270°).

Source	Year	New Year Syzygy
LBAT 1413	-747	335°
LBAT 1413	-746U	325
LBAT 1413	-745	343
LBAT 1414 Obv.I	-730	356
LBAT 1414 Obv.II	-712A	338
LBAT 1414 Obv.II	-711	356
LBAT 1415 Obv.I	-701	337
LBAT 1414 Obv.III	-694	349
LBAT 1417 Obv.II	-667	351
LBAT 1415 Obv.III	-665U	359
LBAT 1415 Obv.III	-664	17
LBAT 1417, LBAT 1416 Obv.III	-650U	343
LBAT 1417, LBAT 1416 Obv.III	-649	1
LBAT 1417 Obv.IV	-631	343

Table 3.1. New Year syzygies fixed by eclipse texts.

The median of these longitudes is 346°, which agrees almost exactly with the repeated assertion of the astronomical compendium MUL.APIN that puts the spring equinox on Nisan 15.

From the first year of Nabopolassar (-624) on, the intercalations in PD³ appear to be complete and reliable (except that the second Ululu in the year -606 should be shifted to the year -607, see Neugebauer-Sachs (1967), p.198).

Shortly after -500, the 19-year intercalary cycle was introduced, and from there on, the beginning of the year was (at least in principle) tightly constricted to the range 358° to 25°, with a median value of 12°. Apart from negligibly small fluctuations from one 19-year cycle to the next, there is a slight secular drift: by the year 0, these three longitudes have increased by 2° each. In -384, an intercalary month was inserted prematurely, so that the following year started with 31°. Note that the longitudes for ordinary years (8° to 25°) and for intercalary years (358° to 7°) do not overlap, and that the lone year with a second Ululu in the 19-year cycle has the earliest beginning (358°).

Thus, the evidence can be summarized in the following Table 3.2 (the years between -624 and -500 were somewhat arbitrarily subdivided into groups of 15 to 19 years when forming ranges and medians).

Years	Solar longitude at New Year syzygy	
	median	range
-747 to -631	346°	325 to 17°
-624 to -610	354	342 to 12
-609 to -595	3	348 to 15
-594 to -576	13	353 to 30
-575 to -557	9	342 to 24
-556 to -538	11	353 to 27
-537 to -519	5	344 to 20
-518 to -500	9	354 to 21
-499 onward	12	358 to 25

Table 3.2. Solar longitude at New Year syzygy.

Thus, between the 8th and the 5th century, the beginning of the year moved by 26° , or almost a month, from about 346° to 12° . While the data are not reliable enough to state so with certainty, it looks as if this shift is due to a discontinuous change made during Nabopolassar's reign.

Because of the large fluctuations and other uncertainties, we should allow a rather wide range for the average beginning of the OB year. Somewhat arbitrarily, we propose to accept chronologies as feasible if they lead to median longitudes in the range between 325° and 45° , that is, if they either lie in the total range (325° to 31°) of the Neobabylonian values, or if they do not deviate more than one month from Fotheringham's average of 16° . But extreme values should be regarded with suspicion.

4. Venus

4.1. Venus phenomena and their recurrence

The motion of Venus is the most regular among the planets in the solar system. During each synodic period (about 20 months) Venus becomes invisible twice: once when it passes between the earth and the sun (inferior conjunction), once when it passes behind the sun (superior conjunction), see Figure 4.1. First and last visibilities repeat themselves fairly accurately after 5 synodic periods or 8 years, more precisely, after 99 synodic months minus 4 days. After 7 or 8 such cycles, the 4-day deficits accumulate to a full month. Thus, after 56 or 64 years (692 or 791 months), Venus phenomena are again in step with the lunar months, but now they fall about two weeks earlier with regard to the solar year.

The duration of the stretches of invisibility is essentially determined by the common longitude of Venus and the sun at conjunction, that is, by its date in the solar year. At inferior conjunction, Venus remains invisible between about 1 day (at longitude $L=320^\circ$) and about 19 days ($L=160^\circ$), while at superior conjunction, the duration of invisibility is between 55 days ($L=285^\circ$) and 70 days ($L=55^\circ$). Of course, these durations are subject to statistical fluctuations of a few days. For details, see in particular van der Waerden (1943).

Figure 4.2 shows the duration of invisibility of Venus, depending on the longitude at conjunction, after van der Waerden. The durations for superior conjunction were slightly raised (by 3 days) to account for the schematic 30-day months used in the Venus Tablet, for the change of date at sunset, and for the fact that van der Waerden gives the times between the visibility limits (which tend to be slightly shorter than the actual times). There is some (meager) empirical evidence from the LB observations that for solar longitudes between 150° and 270° the *arcus visionis* may be somewhat higher (around 1°), thus, in this range of longitudes, the duration of invisibility at superior conjunction should be about 5-10 days longer on the average. For inferior conjunctions, the effect is smaller (1 to 2 days).

The numbers in Figure 4.2 refer to the invisibilities of the Venus Tablet; they correspond to the numbering of the disappearances in Table 4.2 below, and they are positioned at the points corresponding to the calculated longitude of the conjunction for the -1701 chronology and the durations of invisibility given by the Venus Tablet. Questionable entries are enclosed in parentheses. See in particular Section 4.3.1.

After a few 56 or 64 year periods, the phenomena are shifted to different seasons and also get out of step with regard to the duration of invisibility, but then another cycle sets in.

Following a procedure going back to Ptolemy, the theoretical conditions for visibility of Venus in the evening or morning sky are found by calculating the negative altitude h of the sun at the moment when the planet passes through the mathematical horizon (see Fig. 4.3).

Usually, the planet will not be visible when it passes through the horizon, because of atmospheric extinction, but if the so-called *arcus visionis* h exceeds some critical value h_0 , the planet should be visible at some intermediate time between sunset and setting of the planet in the evening, or between rising of the planet and sunrise in the morning.

Since the critical value h_0 was not accurately known, and the random fluctuations even less well, it is necessary to examine the Late Babylonian Venus observations.

4.2. The Late Babylonian Venus observations

From the texts published in LBAT (and some photographs of unpublished tablets) a total of about 100 observations of first and last visibilities of Venus could be culled, ranging in time between the years -461 and -73. The problem with these observations is that they are too good in the sense that most texts do not give the observations as they were observed, but as they should have been observed. That is, they are already corrected for the vagaries of the atmospheric conditions. For instance, based on the high position of Venus, or on its measured duration of shining on day x , the Babylonian observer would conclude that under normal conditions the planet should already have been visible on day $x-1$ or $x-2$. Some texts give regularly, some occasionally, two observations: an 'outer' one, often with a measured duration of shining, and an 'inner' one (by these two terms I distinguish the events according to their closeness to the conjunction with the sun). In many cases, the 'inner' one seems to be not a genuine observation, but rather an educated guess of the observer. Occasionally, and in some texts regularly, only a unique observation is given. The 'inner' and the 'unique' observations show the same statistical behavior, while the 'outer' ones differ substantially (cf. Table 4.1). This agrees with the fact that the summary sections of the LB astronomical diaries only retain the 'inner' observations, after giving both 'outer' and 'inner' ones in the main text a few lines earlier. Even if we carefully weed out dates that are accompanied by the remark 'nu pap', 'I did not watch', our data unavoidably will be biased toward the ideal values.

Within the time span of our LB observations (-461 to -73), there seem to be changes in the practice of observing or of reporting the observations, and there are differences between the treatment of first and last visibilities. The following excerpts were chosen to illustrate some of the features just described.

Last visibility. Early texts give a unique date; later texts give two dates, the first one with a measured duration of shining. For example (LBAT **1237, 110 S.E.): du_6 15 9 *na šá* dele-bat, *in* 19 dele-bat *ina šú ina riñ šú* 'Month VII 15: 36 minutes shining of Venus (*na* is abbreviation for *namirtu*, and refers to the time between sunset and setting of the planet). On about the 19th Venus set in the west in Libra.' Very late texts give a unique date, without duration of shining. Did this arise from a decay of observational practice?

First visibility. Early texts usually give two (or three) dates. For example (LBAT 1387, Artaxerxes I., year 2): *dir-še* 30 13 nu *igi. 1 ina šú ina lu šú. 6 ina nim ina lu igi nim. ina 4 ki 5 igi.* 'Month XII₂ 30 (i.e. the lunar crescent appeared on the 30th day of the preceding month XII, and thus XII had only 29 days; this is the standard convention to indicate month-lengths in these texts), 13 (time degrees, i.e. 52 minutes between sunset and moonset), not seen (!! i.e. the preceding items are not observations, but calculations; according to modern calculation, the moon should indeed have been visible, but with marginal visibility conditions, $\Delta h = 0.2$, see Section 5.1.). On the 1st, in the west, in Aries (Venus) set. On the 6th, in the east, in Aries, it appeared, high, it appeared on about (*ina*) the 4th or 5th.' Later texts add a duration of shining. For example (LBAT 375, 144 S.E.): gu_4 30 ge_6 15 15 *dir an za, si šár du. ge_6* 16 16 *dir an za si šár du. 17 si du. ... 18 dele-bat ina nim ina til múl-múl igi, kur nim-a, 9,30 na-su, in* 15

igi. 'Month II 30 (i.e. the preceding month had 29 days). The night of the 15th and the 15th, clouds captured (? if za is abbreviation for *sabtat*) the sky, north ... (wind) blew. The night of the 16th and the 16th, clouds captured(?) the sky, north ... (wind) blew. On the 17th, north (wind) blew. ... (some lunar observations on the night of the 18th) ... On the 18th Venus appeared in the east in the end of Taurus, brilliant and high, 38 minutes was its shining, it appeared on about the 15th.' In this case, bad weather evidently interfered with the observations.

In view of the poor transmission of the OB data, it is difficult to find out according to which convention the OB astronomers would report their observations. It seems, however, that it is closer to the 'inner' than to the 'outer' observations.

The investigation is reported in more detail in Huber (1977). The texts yield the following collection of *arcus visionis* values on the reported days of first/last visibility in the morning/evening.

'Inner' and 'unique' observations					
WS (22)	WS-1 (22)	ER (23)	ES (21)	ES-1 (21)	WR (26)
2.08					
3.136889	6	2			
4.002679	1377	6	68	9	
5.333469	01444568	5677788	06888999	0289	2347889
6.	234589	012488	13345688	00011355589	0112444455578
7.1	58	125	134	01357	123459
8.8		0138			
9.		1			
10.	3				
'Outer' observations					
WS (8)		ER (19)	ES (8)		WR (11)
5.					678
6.4			2		789
7.016		2468	0024888		22359
8.44		0002222356			
9.7		249			
10.5		4			
11.		1			

Table 4.1. Stem-and-leaf display of Late Babylonian *arcus visionis* values of Venus (in parenthesis: number of observations).

We use the common abbreviations WS, ER, ES, WR for Western Setting, Eastern Rising, Eastern Setting, and Western Rising. Table 4.1 summarizes the Late Babylonian *arcus visionis* values in a very compact fashion, in the form of so-called stem-and-leaf displays. They are to be read as follows. To the left of the first vertical line, the integral part of h is given, to the right, the first decimal digit. For instance, the upper left hand corner of the table conveys that

there are two 'inner' WS-observations with h between 2.0 and 2.9, namely 2.0 and 2.8, and there are six values between 3.0 and 3.9, namely 3.1, 3.3, 3.6, 3.8, 3.8, 3.9. Figure 4.4 shows the same data graphically; the boxes give the median and the two quartiles, and the whiskers extend to the extreme values (except that some putative outliers are marked by stars).

The *arcus visionis* values for WS, where the daily changes are very large (0.6 to 1.6 degrees), are surprisingly low, much lower than the values for the other three events, but the values of the preceding day (WS-1) are in the right neighborhood. I therefore conjecture that the events WS (and ES) do not denote the day of last visibility, but the day of first invisibility. Incidentally, the terminology of the schematic section of the OB Venus Tablet suggests that the same convention holds also there.

From Table 4.1 one obtains the following median values for the *arcus visionis* (i.e. one-half of the 'inner' observations falls below, one-half above this value):

	WS	WS-1	ER	ES	ES-1	WR
Median	4.4	5.5	6.1	6.1	6.3	6.4
Median minus 1/2 daily change		5.0	5.6		6.2	6.3
Schoch's limit	5.2		5.7		6.0	6.0

Schoch's limit, which is traditionally used to calculate theoretical visibility conditions (the planet is supposed to be visible if the *arcus visionis* exceeds the limit), should be compared not to the median, but to the median minus one-half of the daily change, and then turns out to be surprisingly accurate: it is essentially exact for inferior conjunctions, and it may tend to be too optimistic (by about one day) for superior conjunctions.

4.3. The Old Babylonian Venus observations

Apart from minimal changes (to be mentioned below) we followed the text established by E. Reiner and D. Pingree, *The Venus Tablet of Ammisaduqa*, Bibliotheca Mesopotamica, Vol. 2,1 (1975). We quote this edition as RP.

4.3.1. Data screening

To avoid possible misunderstandings, I must present the analysis of these very poor data in considerable detail. As a rule, apparent gross errors and conjectural emendations were included in the astronomical calculations, but otherwise treated like missing values and excluded from statistical tests. However, I struggled with the Venus Tablet data long enough so that the treatment is not wholly consistent between calculations I did seven years ago (i.e. before RP) or more recently.

The text contains dates of 49 distinct phenomena; if it ever was complete, it covered 52. The data set is the worst I ever have encountered as a statistician. From the number of internal inconsistencies (between dates of disappearance and reappearance and the stated duration of invisibility) and of discrepancies between duplicates, one may guess that at least 20% to 40% of the dates must be grossly wrong. This entails that we must perform some data screening to eliminate the clearly wrong values, and then we must employ statistical techniques that are robust (insensitive to the presence of a moderate number of gross

errors).

It should be emphasized that this screening is independent of chronological assumptions. We already noted that Venus phenomena show an approximate 8-year periodicity. About 80% of the preserved dates more or less match this periodicity, while some 20% (most of the dates marked B in Table 4.2) are wildly off the mark, and presumably are gross scribal errors. The remaining 80% may still contain some less gross scribal and observational errors (e.g. caused by poor weather conditions). Among them, we shall throw out groups which seem to be affected by a common pattern of errors, for example the entire last section of the text, which seems to be more corrupt than the rest.

				-1701	-1645	-1637	-1581
1	WS	1 XI 15	G I	5.54	10.31	3.71	9.98
2	ER	1 XI 18	G I	5.88	4.33	8.13	4.88
3	ES	2 VIII 11	G I	7.78	8.42	7.56	7.72
4	WR	2 X 19	G I	7.17	6.26	7.12	6.17
5	WS	3 VI 23	G I	9.65	8.79	5.78	5.73
6	ER	3 VII 13	G I	4.46	1.69	7.28	5.91
7	ES	4 IV 2	G I	6.98	6.68	6.03	5.70
8	WR	4 VI 3	G I	5.22	5.43	5.89	6.07
9	WS	5 II 2	G I	-0.37	4.77	-1.89	3.04
10	ER	5 II 18	B	11.45	9.70	12.24	11.46
11	ES	5 IX 25	G I	5.41	6.54	5.81	7.00
12	WR	5 XI 29	G I	6.65	5.50	6.65	6.08
13	WS	6 VIII 28	G I	5.25	6.20	2.09	2.95
14	ER	6 IX 1	G I	7.59	3.28	8.09	5.59
15	ES	7 V 21	G I	6.94	7.66	6.55	7.29
16	WR	7 VIII 2	G I	6.26	5.86	6.43	5.94
17	WS	8 IV 25	B	-13.99	-10.46	-15.39	-13.40
18	ER	8 V 2	B	17.46	11.86	16.49	12.14
19	ES	8 XII 25	G I	6.42	6.76	6.27	7.14
20	WR	9 III 11	C	6.06	5.64	6.42	5.89
21	WS	9 XII 11	G I	6.68	9.89	3.30	9.55
22	ER	9 XII 15	G I	6.27	5.54	9.35	6.19
23	ES	10 VIII 10	G I	6.92	7.81	6.70	7.10
24	WR	10 X 16	G I	7.51	6.32	7.45	6.47
25	WS	11 VI 26	G I	4.50	3.70	0.96	1.51
26	ER	11 VI ₂ 8	M I	1.96	-0.80	4.83	3.43
27	ES	12 I 9	B	11.21	10.86	10.38	10.66
28	WR	12 VI 25	B	12.52	11.85	12.34	11.93

				-1701	-1645	-1637	-1581
29	WS	13 II 5	B	-11.30	-6.58	-12.99	-6.90
30	ER	13 II 12	M	10.25	8.73	11.38	10.22
31	ES	13 X 21	G I	5.43	6.83	5.83	7.01
32	WR	13 XI 21	B	-2.48	-3.47	-2.36	-2.71
	WR	13 XII 21	C	5.36	4.49	5.37	4.81
33	WS	14 VII 10	B	34.57	29.63	28.96	24.33
34	ER	14 VIII 27	G I	6.62	3.69	10.00	7.72
35	ES	15 V 20	G I	6.32	6.80	5.94	6.47
36	WR	15 VIII 5	G I	7.58	6.97	7.78	7.18
37	WS	16 IV 5	G I	2.59	8.01	3.46	8.51
38	ER	16 IV 20	G I	7.45	2.04	7.53	3.75
39	ES	16 XII 15	M I	7.35	7.98	7.44	8.45
	ES	16 XII 25	C	5.98	6.27	5.78	6.38
40	WR	17 III 25	M	9.33	9.36	10.01	10.02
	WR	17 III 4	C	5.50	4.71	5.53	4.91
41	WS	17 XII 10	G I	1.52	4.86	-0.24	4.61
42	ER	17 XII 14	M I	8.92	8.50	11.38	9.54
43	ES	18 IX 12	C	5.54	6.20	5.09	5.51
44	WR	18 XI 16	C	8.39	7.45	8.59	7.54
45	WS	19 VI ₂ 1	B	15.48	15.41	13.56	14.97
46	ER	19 VI ₂ 17	B	-22.90	-24.71	-19.10	-21.19
47	ES	20 III 25	G	6.70	6.28	5.63	5.33
48	WR	20 VI 24	M	8.46	8.55	9.06	9.40
	WR	20 VI 1	C	5.96	6.11	6.67	6.94
49	WS	21 I 27	B	-5.71	-0.73	-7.41	-1.03
50	ER	21 II 3	G	6.11	5.74	8.12	7.68
51	ES	21 X 28	M	3.17	4.17	3.50	4.65
52	WR	21 XII 28	M	8.39	7.26	8.40	7.57

Table 4.2. The Venus Tablet data.

The data are classified as good (G), mediocre (M), or bad (B), depending on how well they are able to fit at least one chronology fitting the majority of the data; C stands for conjecture, and dates included in the main calculations are marked I. The *arcus visionis* values for the four main chronologies are also given (they formed the basis for the G,M,B-classification).

A detailed description of the screening process follows. The events are identified by their numbers in Table 4.2.

Faulty month-names.

- #7,#21 Two nonsensical month-names were emended (VII in IV and III in XII), and the altered dates were retained.
- #32 The duration of invisibility between #31-32 is much too short (cf. Section 4.1). A comparison with the sequence of events 8 years earlier, taking the month VI₂ in year 5 into account, suggests that in #32 XI should be changed into XII. But I felt safer deleting this entry, there are too many uncertainties involved here. By the way, I followed Langdon, who 'read 21 on the tablet clearly' (LFS p.8¹⁰), against RP (which prefers 11, plainly preserved on another manuscript).

Conjectural fill-ins.

- #20 The WR is missing, the text puts the WS on III 11, and has a nonsensical invisibility of 9 months 4 days at inferior conjunction. I conjecture that III 11 really was the date of the WR, and that an ancient copyist skipped a line, misled by the same number 11 in the date for the WS. We mark #20 as a conjecture and do not use it in the analysis.
- #43-44 These two events were displaced by a schematic insertion, which gives rather unrealistic, constant durations of invisibility of 7 days at inferior, and of 3 months at superior conjunction. Weir (1972, p.27) conjectured that a textual variant for the pair #11-12 might preserve the missing dates for year 18. They are marked as conjectures and are not used in the analysis.
- #48 The text has VI 24, with an incompatible interval (2 months 6 days). Reconstructing the date of the WR from the ES and the interval gives VI 1 and a much better fit, but we disregarded it in the analysis.

Impossible durations of invisibility.

- #27-28 The interval is impossibly long, so at least one date must be grossly wrong. Since neither fits with any chronology fitting a majority of the data, we drop both.
- #33 The interval #33-34 is much too long; a comparison of #13-16 with #33-36 suggests that #33 is the offender, so we drop it.
- #39-40 The interval of invisibility (3 months 10 days) is about a month too long. Pingree (RP p.21, bottom) reconstructs the dates XII 25 and III 4, and the latter is indeed attested as a variant. We felt the reconstruction was too conjectural to be used; we dropped #40 and kept #39 with XII 15.

Invisibility 7 days at inferior conjunction.

- #17-18, 29-30, 49-50 These three pairs have 7 day invisibility. All three pairs give a poor to impossible fit for at least one of the two events, for any chronology fitting the majority of the data. We conjecture that these dates were interpolated with the help of the schematic 7 day invisibility of the schematic insertion at year 18, mentioned above. The safest procedure is to drop all 6 dates.

Last years.

#45-52 At least 5 of these 8 dates give a poor fit for any chronology fitting the majority of the data. One may wonder whether they belong to Ammisaduqa at all. We believe they continue the preceding observations, but are badly garbled. If they would not belong here, it would be difficult to find a home for them. For instance, the most likely candidate for #45-46 is Ammiditana year 32, which however has an attested XII₂, not a VI₂. If the pair #45-46 belongs to Ammisaduqa year 19, then the date VI₂ 17 is about right for WS (not for ER), so one might perhaps conjecture that here a scribe tried to restore a badly broken text on the basis of the isolated date VI₂ 17 and the duration of invisibility, mistaking the former for the date of ER. Anyway, we cannot gain much by keeping this section in, so we may just as well stay on the safe side and drop it entirely.

Other reasons.

#10 This date agrees so poorly with any chronology fitting the majority of the data (it is several days too late) that I decided to drop it, though it may very well be genuine and correspond to an observation delayed by bad weather; cf. the *arcus visionis* values for 'outer' observations in Table 4.1. This is in fact the only item rejected solely because it disagreed with calculation, without being under suspicion for other reasons, like internal inconsistencies, or for belonging to a group showing a suspicious pattern.

This leaves us with 31 of the 49 preserved observations. It would be difficult to screen out more observations without prejudging the chronology.

After establishing a particular chronology we may go back and check also the rest of the data against calculation. If we accept the -1701 solution, it appears that 3 or 4 more dates are wrong: #9, 26, 41 and possibly 39. It would thus seem that two fairly long sections of the tablet, namely #26-33 and #39-52, are almost throughout corrupt, while most of the rest, namely 25 dates (or just barely over 50% of the 49) are in good shape. Four more observations (#30, 42, 47, 50) interspersed in the bad sections are also in good (but perhaps accidental) agreement with calculation.

Pingree (RP p.21ff.) raises the question whether the three Venus periods covered by the tablet, more precisely, the groups #1-19, #21-42 and #45-52, really belong together and continue each other in the traditionally assumed way. We shall now show that there can be hardly any doubt that the second group continues the first one. We simply classify the observations as early or late, depending on whether the *arcus visionis* value is larger or smaller than the median of the Late Babylonian 'inner' values for the particular event (for a WS or ES, large values are early, for a WR or ER, large values are late). The following Table 4.3.a shows the results for the four main chronologies; before the slash, the number of early observations is given, after the slash, the number of late ones.

data	years	Chronology			
		-1701	-1645	-1637	-1581
50	1-8	11/8	16/3	5/14	13/6
	9-17	10/13	16/7	6/17	13/10
	19-21	3/5	4/4	2/6	2/6
	all	24/26	36/14	13/37	28/22
38	1-8	11/6	16/1	5/12	13/4
	9-17	7/10	13/4	3/14	10/7
	19-21	1/3	1/3	0/4	0/4
	all	19/19	30/8	8/30	23/15
31	1-8	11/5	16/0	5/11	13/3
	9-17	6/9	12/3	3/12	9/6
	all	17/14	28/3	8/23	22/9

Table 4.3.a. The early/late counts for the OB Venus observations: Venus periods.

Thus, for the -1701 chronology and the data set containing 50 observations, during the first 8 years of Ammisaduqa, 11 observations are early, 8 late, while for years 9-17, 10 are early and 13 late. The first two 8-year periods show almost the same behavior across the four chronologies: for -1645, the observations are predominantly early, for -1637 predominantly late, and the behavior gets more pronounced, the more gross errors we throw out. (In the first group with 50 data, we used all except #43-44, in the second group with 38 data, also #17, 18, 27, 28, 29, 30, 32, 33, 45, 46, 49, 50 were excluded, and in the third set, only the 31 included in the main calculations and marked I in Table 4.2 were kept.) This same behavior of the first and of the second 8-year period can only mean that they are either immediately consecutive, or they are separated by something like 120 years.

Similarly, one can show that all four phenomena (WS, ER, ES and WR) move in parallel, see Table 4.3.b. Note how between -1645 and -1637, the early/late pattern of WS, ER and WR practically switches from all early to all late, while ES switches from all early to a middle position. Since in 8 years the phenomena shift 4 days on the average relative to the lunar calendar, this means that shifts of 2 days are very visible. Incidentally, if we compare the counts for high and low arcus visionis values (instead of early/late), we find that the OB values tend to be slightly higher than the LB 'inner' values (the difference is barely significant on the 5% level), but considerably lower than the LB 'outer' values. (For instance, we can read off from Table 4.3.b that for the -1701 chronology and for the data set with 31 items, we have $5+5+7+4=21$ high and $3+3+2+2=10$ low values.)

data	event	Chronology			
		-1701	-1645	-1637	-1581
50	WS	7/6	9/4	3/10	7/6
	ER	4/9	9/4	2/11	6/7
	ES	9/3	11/1	6/6	9/3
	WR	4/8	7/5	2/10	6/6
	total	24/26	36/14	13/37	28/22
38	WS	5/3	7/1	1/7	5/3
	ER	3/6	7/2	1/8	5/4
	ES	8/3	10/1	5/6	8/3
	WR	3/7	6/4	1/9	5/5
	total	19/19	30/8	8/30	23/15
31	WS	5/3	7/1	1/7	5/3
	ER	3/5	7/1	1/7	5/3
	ES	7/2	9/0	5/4	8/1
	WR	2/4	5/1	1/5	4/2
	total	17/14	28/3	8/23	22/9

Table 4.3.b. The early/late counts for the OB Venus observations: the four phenomena.

4.3.2. The Venus Chronologies

It can be seen from Tables 4.3.a and b that for some chronologies the phenomena fall almost uniformly earlier (or later, respectively) than expected. The effect is strong enough to render unlikely the middle two chronologies (we can use the so-called sign test to test the hypothesis that the asymmetry between the early and late counts has been caused by chance, and it rejects this hypothesis on the 1%-level, whether we use the purged or the unpurged data sets). Note that the -1581 chronology performs better with the less purged sets (much of its support comes from the last years 19-21).

The following Table 4.4 summarizes the data for the four main chronologies in stem-and-leaf displays, comparing it simultaneously with the Late Babylonian data. As already pointed out, the two sets show much the same behavior, except that the OB Western Settings appear to be somewhat more spread out.

 WESTERN SETTING WS (not WS-1)

Late Bab. -1701 -1645 -1637 -1581

-1.			9	
-0.	4		2	
0.				
1.	5		0	5
2.	08	6	1	
3.	136889		7	357 00
4.	002679	5	89	6
5.	333469	25	8	7
6.		7	2	
7.	1			
8.	8		08	5
9.		6	9	6
10.			3	0
11.				

EASTERN RISING ER

Late Bab. -1701 -1645 -1637 -1581

-1.				
-0.			8	
0.				
1.			7	
2.		0	0	
3.	2		37	48
4.	6	5	3	8 9
5.	5677788	9	5	69
6.	012488	36		2
7.	125	46		35 7
8.	0138	9	5	11
9.	1			4 5
10.				0
11.				4

EASTERN SETTING ES					
Late Bab.	-1701	-1645	-1637	-1581	
4. 68					
5. 06888999	44		889	7	
6. 13345688	3499	57788	0367	5	
7. 134	048	78	46	001137	
8.		04		5	

WESTERN RISING WR					
Late Bab.	-1701	-1645	-1637	-1581	
4.					
5. 2347889	2	459	9	9	
6. 0112444455578	26	33	46	1125	
7. 123459	256	0	148	2	
8.					

Table 4.4. Stem-and-leaf display of arcus visionis values of Venus.

Since the Wilcoxon test is more powerful than the sign test in such situations, I used the latter for a more comprehensive investigation (see, e.g., E. L. Lehmann (1975), pp. 120ff.). Specifically, for each of about 20 tentative chronologies, I calculated the Wilcoxon test statistics comparing the LB and the OB arcus visionis values, separately for each phenomenon.

Then I normalized the test statistics (so that under the hypothesis of a correct chronology they should have mean 0 and variance 1), and finally I added them with the proper signs and divided by 2. The resulting sum then is approximately standard normal, and the goodness of fit of any chronology can be judged in terms of the probability that a normal quantity with mean 0 accidentally exceeds the observed sum in absolute value.

These probabilities are listed in Table 7.1. Some years ago, I had done these tests with fuller data sets (mostly with 38 observations, namely without those marked B in Table 4.2, but sometimes, namely before RP became available, with 41 items, cf. Huber (1977)). Now, I redid the tests with the more stringently purged set containing 31 items. Since it may be interesting to see the differences caused by data selection, I put the results side by side (the main difference is due to the inclusion/exclusion of the years 19-21). It can be seen also from this table that the two 'middle' chronologies (-1645,-1637) agree poorly with the Venus Tablet data: for the former, the events are systematically too early in the lunar calendar, for the latter too late, and the difference is statistically significant at least on the 1%-level. Compare also Tables 4.3.a and 4.3.b, and the discussion in Sections 5.4.1 and 7.

5. Month-lengths

5.1. Calculation of crescent visibility

The actual sighting of the thin lunar crescent depends on weather conditions and on the luck of the observer; calculation can at best give approximations valid for average good weather. They are done as follows.

The position of the moon is calculated at the time of sunset (i.e. when the sun is in the mathematical horizon) for the first few evenings after the new moon. The crescent is supposed to become visible on the first evening for which the altitude of the moon at sunset exceeds a certain value h ; h depends on the difference Δ in azimuth between sun and moon. This h has been determined empirically; the tables given in PVN (Table E21) and in LFS (Table K, p.95) differ slightly, cf. Table 5.1 and Fig. 5.1. We have followed PVN, while PD³ is based on LFS.

Δ	h	
	PVN	LFS
0	10.4°	10.7°
1	10.4	10.7
2	10.3	10.6
3	10.2	10.5
4	10.1	10.4
5	10.0	10.3
6	9.8	10.1
7	9.7	10.0
8	9.5	9.8
9	9.4	9.6
10	9.3	9.4
11	9.1	9.1
12	8.9	8.8
13	8.6	8.4
14	8.3	8.0
15	8.0	7.6
16	7.7	7.3
17	7.4	7.0
18	7.0	6.7
19	6.6	6.3
20	6.2	
21	5.7	
22	5.2	
23	4.8	

Table 5.1. Limiting altitude for lunar crescents.

Thus, the crescent is assumed to become visible on the first evening for which the difference

$$\Delta h = h_{\text{moon}} - h$$

is greater or equal zero.

I calculated all 33000 lunar crescents for Babylon (geographical longitude 44.5° and latitude 32.5°) between the years -2456 and +212. The following

statistics may be of some interest.

There were no 28-day months at all, but there were 20 months with 31 days. We believe that the Babylonian months never exceeded 30 days (even if the crescent did not appear), and therefore, the 31st day should be carried over to the next month.

After carrying over the additional days of the 31-day months, there were 15491 29-day months (48.9%) and 17509 30-day months (53.1%).

The 29- and 30-day months follow each other in a quite irregular and not easily predictable sequence, but which is not really random (i.e. there are discernible differences between this sequence and one obtained by tossing a biased coin). I checked it for periodicities by comparing month-lengths spaced up to 3000 months apart. The most pronounced period is 669 months or 54 years: month-lengths spaced 669 months apart agree in 81% of the cases. In particular, there are fewer and shorter runs (sequences of consecutive months of equal length) than in a truly random sequence. I found 410 runs of three consecutive 29-day months, and 100 runs of five consecutive 30-day months; longer runs did not occur.

On the day before theoretical first visibility, Δh can be as low as -14.3° , and on the day of first visibility, it can be as high as 14.4° . Between these two days, the value of Δh increases by at least 6.2° and by at most 14.5° .

5.2. Late Babylonian astronomical texts.

Crescent visibility data was extracted from observational texts published in LBAT, namely from the Diaries No. 160, 171, 176, 179, 181, 191, 197, 205, 222, 232, 236, 247, 248, 249, 271, 283, 304, 312, 339, 367; the Goal Year texts No. 1214, 1220, 1225, 1230, 1232, 1235, 1238, 1241, 1249, 1251, 1257, 1263, 1265, 1268, 1285, 1291, 1334 (S.E. 223); the planetary texts No. 1387+1388, 1390, 1391 (S.E. 122), 1394, 1395, 1399, 1400, 1407; and the lunar texts No. 1431, 1433, 1435+1443 (S.E. 224). Each month-length gives information about two crescents; if we count also crescents implied by month-length, we obtain a total of 602 distinct crescents.

Not all texts distinguish between actual observations and calculations substituted for them when the weather was poor. Thus, these crescent data do not represent actual sightings, but idealized ones: they give the best judgment of the Babylonian observer on when the crescent became visible in 'reality', that is under good weather conditions. We do not know how these calculations were done -- whether on the basis of observations made a few days earlier or later, or 18 years earlier, or on the basis of mathematical astronomy (i.e. whether with the help of direct observations, or of Goal Year texts, or of texts of the type published by O. Neugebauer in ACT), or using a combination of all three. Thus, the agreement with modern calculation can be expected to be perhaps slightly inferior to that corresponding to observations made under ideal conditions, but superior to actual observations under imperfect conditions.

The distribution in time of these crescent observations is shown in Table 5.2. For purposes of comparison, we also list the distribution of crescent observations gathered from month-lengths occurring in economic-administrative texts, see Section 5.3. Note that the astronomical texts predominantly date from the time after the invention of mathematical astronomy (around 500 B.C.), while the economic texts predominantly date from the time before.

Years	Number of lunar crescents	
	astronomical texts	econ.-admin. texts
-650 to -601	0	27
-600 to -551	8	79
-550 to -501	0	160
-500 to -451	73	15
-450 to -401	119	4
-400 to -351	91	0
-350 to -301	54	2
-300 to -251	21	2
-250 to -201	98	4
-200 to -151	105	4
-150 to -101	25	0
-100 to -51	8	2
total	602	299

Table 5.2. Number of attested lunar crescents.

Among the 602 crescents, there are 34 discrepancies between observation and calculation. One of them clearly is a scribal error in the recorded month-length that can be corrected on the basis of the adjacent month-lengths (it would throw the following observations out of step). Thus, there were $33/602=5.5\%$ misses. Of the 33 genuine discrepancies, 30 correspond to marginal visibility conditions with $|\Delta h| < 1.0^\circ$, that is, to cases where the altitude of the moon was within $\pm 1^\circ$ of the theoretical curve deciding visibility (Fig. 5.1). The remaining 3 may be gross errors; they have Δh -values of -1.3, -1.2 and 1.8 respectively, and two of them come from the same, poorly preserved tablet (LBAT 1268).

The following histogram shows the distribution of crescents with small Δh -values (Table 5.3).

	not sighted	Δh	sighted	
44	xxxxxxxxx	-0.9		15
	xxxxxx	-0.8		
	xxx	-0.7	xxx	
	xxx	-0.6	xx	
	xxxxxxxx	-0.5	x	
	xxxxxx	-0.4	xxx	
	xxxx	-0.3		
	xxx	-0.2	x	
	xxxx	-0.1	xxxx	
		-0.0	x	
15		0.0	xx	38
	x	0.1	xxxxxxxx	
	x	0.2	x	
	x	0.3	xxx	
	xx	0.4	xxxxxx	
	xxx	0.5	xxxxxx	
	xxx	0.6	xx	
	x	0.7	xxx	
	xx	0.8	xx	
	x	0.9	xxxxxxxx	

Table 5.3. Astronomical texts. Crescents with $|\Delta h| < 1.0$

Figure 5.2 plots Δh against the difference Δ in azimuth. According to the PVN criterion the crescent is visible if Δh is positive, while according to the LFS criterion it is visible if Δh is above the broken line (the broken line plots the difference between the two columns of Table 5.1). Note that the LFS procedure would remove 4 discrepancies and introduce 12 new ones, thereby increasing the frequency of missed crescents to $41/602 = 6.8\%$. It is evident from the figure that the PVN criterion is almost optimal for this kind of astronomical texts; one could obtain an even slightly better agreement by lowering h by about 0.1° in the range $0 \leq \Delta < 11^\circ$.

Clearly, if we disregard gross errors, the probability of seeing the crescent is almost 0 for $\Delta h = -1$, almost 1 for $\Delta h = 1$, and it increases monotonically in between. It is easy to construct a simple probabilistic model showing such a behavior. For instance, disregarding gross errors, the following model represents the data well:

- if $\Delta h < -1^\circ$, the crescent is never seen;
- if $-1 \leq \Delta h \leq 1$, the crescent is seen with probability $(1 + \Delta h) / 2$;
- if $\Delta h > 1$, the crescent is always seen.

This model implies for example that given $-1 < \Delta h < 0$, the crescent is seen with probability 0.25, and given $0 < \Delta h < 1$, it is seen with probability 0.75. These probabilities agree well with the observed ratios $15/59 = 0.25$ and $38/53 = 0.72$ (cf. Table 5.3).

5.3. Late Babylonian economic-administrative texts.

Sachs collected 93 30-day months and 4 positively attested 29-day months from Neo- and Late Babylonian economic-administrative texts. Later on, E. Leichty contributed 58 additional 30-day months. Since Leichty cautioned about possible errors or typos in his catalogue, we kept the two lists separate in the analysis and joined them only at the end. The material is shown in Section 1 of the Appendix.

The 95 uniquely dated months of the Sachs material involve a total of 184 crescents. Calculation and texts disagree for $32/184=17.4\%$ of the crescents and for $32/95=33.7\%$ of the months. Of the misses, 20 involve marginal visibility conditions with $|\Delta h| < 1$. Among the remaining 12 misses, 11 have Δh values of

-1.5, -1.4, -1.3,
1.7, 2.0, 2.2, 2.6, 3.5, 4.4, 5.0, 5.3.

They may either be explained by exceptional visibility conditions, or as gross errors. The twelfth (#5903) seems to be a gross error (the lengths of the immediately following months do match).

Such a 'gross error' may have many different causes. Perhaps the text was written immediately after sunset, before the crescent had been seen (and thus day 30 was the correct date), cf. Section 3. Perhaps the ancient scribe was negligent, or perhaps he was using a schematic day 30 to indicate a last-of-the-month date. Sometimes, the errors are modern misreadings and typos.

If we switch to the LFS-criterion (Table 5.1), we remove 7 discrepancies and introduce 2 new ones (thus reducing the number of misses from 32 to 27). With PD³ we obtain even fewer, namely only 24 misses, but two or three discrepancies between H and PD³ (#5687, #5781, and possibly #5597) seem to be caused by gross errors in PD³.

Neither of the two criteria is clearly superior (LFS did worse than PVN for the astronomical texts). Moreover, the numbers involved are small, and the apparent superiority of LFS for the economic texts need not stand up if the data material were increased (the observed difference is not statistically significant). So I felt it was not worthwhile to repeat all the calculations, and I decided to stick to the PVN criterion also for the non-astronomical texts. Figure 5.3, showing the crescents with marginal visibility conditions, indicates that for the economic-administrative texts the boundary between visibility and non-visibility is much more diffuse in any case.

If we count only 'bad misses', that is, only those with $|\Delta h| \geq 1$, we obtain disagreement rates of $12/184=6.5\%$ for the crescents and $12/95=12.6\%$ for the months.

The Leichty material gives 18 misses, 13 of them being 'bad', and disagreement rates of $18/113=15.9\%$ for the crescents, $18/58=31.0\%$ for the months. The fraction of bad misses is somewhat higher ($13/113=11.5\%$ for the crescents and $13/58=22.4\%$ for the months) than for the Sachs data, and may correspond to Leichty's warning about errors and typos, but the difference is not statistically significant on the 5% level. After that, I decided we could not go much wrong by joining the two data sets together.

The following histogram shows the distribution of crescents with small Δh -values (Table 5.4).

not sighted	Δh	sighted
xxxxx	-0.9	
xxx	-0.8	xx
x	-0.7	
xxxxx	-0.6	xx
22 x	-0.5	11
xx	-0.4	
x	-0.3	xx
xx	-0.2	xx
xx	-0.1	xx
	-0.0	x
x	0.0	x
xxxx	0.1	x
xx	0.2	x
x	0.3	xx
x	0.4	xxx
14 x	0.5	14
	0.6	xx
x	0.7	x
x	0.8	
xx	0.9	xxx

Table 5.4. Economic-administrative texts. Crescents with $|\Delta h| < 1.0$

These NB economic-administrative texts are similar to the OB non-astronomical material. They have two main uses:

- (1) They allow us to estimate the agreement between observed and calculated month-lengths that we can expect for a correct chronology (namely about $50/153=33\%$ misses and $25/153=16\%$ 'bad misses').
- (2) They can be used to find good scoring methods (should we judge tentative chronologies in terms of the number of misses, or 'bad misses', or something else?)

In passing we note that the average month-length is 29.53 days, so for a random alignment we can expect that about 53% of the 30-day months will match. The corresponding miss rate of 47% is uncomfortably close to the above miss rate of 33% for a correct chronology.

We now consider the problem of finding good scoring methods for judging tentative chronologies. If consecutive month-lengths are available, one should in principle judge the agreement in terms of the crescents, not of the month-lengths. In practice, this is tricky because of missing data and because of the presence of gross errors, that is, of day 30 dates in months which had only 29 days. Since we have only few consecutive month-lengths anyway, I decided to stick to the somewhat simpler methods appropriate for isolated months.

The observed batches of 95 (Sachs) or 58 (Leichty) or 153 (both together) months were aligned along the calculated sequence first in their proper places, and then the batches were shifted along the calculated sequence and aligned in 19999 other positions.

Thus, among the 20000 alignments, one corresponds to the 'true match', where each observed month-length is paired with its true counterpart in the

calculated sequence, while in the remaining 19999 alignments, each month-length is matched with a wrong partner. The quality of each of the 20000 matches was judged according to four different scoring methods:

- (1) by counting misses,
- (2) by counting 'bad misses' only ($|\Delta h| \geq 1$),
- (3) by a method based on a probabilistic argument (see below), assuming a probability $p = (1 + \Delta h) / 2$ for seeing the crescent,
- (4) same as (3), but with $p = (1.3 + \Delta h) / 2.6$ for $|\Delta h| \leq 1.3$.

In no case did the true match stick out and achieve the best score. For instance, with the 95 Sachs data, the true match had 32 misses, but there were 266 alignments (1.33% of 20000) with 32 or fewer misses, so it did not even make it into the top 1% group (see Table 5.5). Counting bad misses performed better for the Sachs data, but worse for the Leichty data. For the combined data set, misses and bad misses did about equally well.

Method	data	best score	score of true match	rank of true match
(1) misses	Sachs (95)	24	32	266 = 1.33%
	Leichty (58)	15	18	96 = 0.48%
	combined (153)	46	50	17 = 0.085%
(2) bad misses	Sachs	11	12	3 = 0.015%
	Leichty	7	13	1796 = 9.0%
	combined	22	25	5 = 0.025%
(3) $p = (1 + \Delta h) / 2$	Sachs	56.8	64.4	14 = 0.07%
(4) $p = (1.3 + \Delta h) / 2.6$	Sachs	53.9	61.9	18 = 0.09%

Table 5.5. Comparison of scoring methods.

5.3.1. The probabilistic scoring method

The probabilistic scoring methods (3) and (4) had been developed on the basis of a slightly improved version of the probability model for seeing the crescent mentioned at the end of Section 5.2. The improvement consisted in making explicit allowance for the occurrence of gross errors. Basically, the score function is the negative logarithm of the likelihood of the observed sequence of month-lengths for the particular alignment.

However, this approach was not pursued further when it became clear (i) that the probability model did not really apply to the non-astronomical texts, and (ii) that this very complex scoring method did not perform better than the simple ones based on either misses or bad misses.

5.4. Month-lengths of Babylon I

Section 2 of the Appendix lists the known intercalations, while Section 3 lists the months with an attested day 30 dated during the time of the Hammurapi dynasty.

For our purposes only such segments are useable for which (i) the intercalations are complete with a high probability, and which (ii) contain a large

number of attested month-lengths. So far, only three segments would seem to qualify: Ammisaduqa years 1-16, Ammiditana years 22-37, and Hammurapi year 31 to Samsuiluna year 11.

We first illustrate the statistical approaches to be used by analyzing the Ammisaduqa month-length data, and then we discuss some methodological issues.

5.4.1. Ammisaduqa years 1-16

In the case of Ammisaduqa, the intercalary years are fixed both by the Venus Tablet and by contemporary economic texts. The order of the years after year 16 is unknown. There is some evidence (from an unpublished tablet mentioned in LFS p. 61) that the year preceding 17+a contained a VI₂; the year 17+d has an attested VI₂ and 17+a has a XII₂. On the other hand, the Venus Tablet attests 19 VI₂ and requires an intercalation in 20. Hence the identifications 17+d=19, 17+a=20 are likely, but there remain enough uncertainties that we decided not to rely on month-lengths attested after year 16.

Years 1-16 contain 21 attested 30-day months. If the chronology chosen is correct, then the probability that a single month-length is a miss or a bad miss is about $p=50/153=0.3268$ and $p=25/153=0.1634$ respectively (these are the relative frequencies obtained for the Neo- and Late Babylonian texts). The probability of obtaining k or more misses (bad misses) in 21 independent trials then is given by the following table:

k	misses $p=0.3268$	bad misses $p=0.1634$
0	1.0000	1.0000
1	0.9998	0.9764
2	0.9972	0.8796
3	0.9851	0.6906
4	0.9476	0.4567
5	0.8659	0.2512
6	0.7309	0.1147
7	0.5561	0.0436
8	0.3744	0.0139
9	0.2200	0.0037
10	0.1117	0.0008
11	0.0486	0.0002
12	0.0180	0.0000
13	0.0056	0.0000
14	0.0015	0.0000
15	0.0003	0.0000
16	0.0001	0.0000
17	0.0000	0.0000

Table 5.7 Probability of obtaining k or more misses (bad misses) for a correct chronology in 21 trials.

Thus, depending on the stringency one requires, it is unlikely that a correct chronology would give more than about 10-12 misses or 6-8 bad misses.

The numbers of misses and bad misses obtained for the different Venus chronologies are listed in Table 7.1, together with the minimal rejection levels

read off from Table 5.7. It can be seen that among the four principal Venus chronologies (-1701,-1645,-1637,-1581), the two middle and the short ones can be rejected on a 2% significance level because of the high number of misses, while the long chronology shows an agreement which is even slightly better than expected. (According to Table 5.7, a correct chronology would give 6 or fewer misses with probability $1-0.5561=0.44$, and 2 or fewer bad misses with probability $1-0.6906=0.31$.)

This confirms the findings from the Venus data, which also favored the long chronology, allowed the rejection of the middle two and rendered unlikely the short one.

Thus, if we believe that one of the four main Venus chronologies is correct, it must be the long one by elimination of the other three. But, conceivably, all four might be wrong. Thus we shall try to check whether the agreement for the -1701 chronology is better than the best agreement to be expected among four randomly chosen wrong chronologies.

In principle, we could use a similar approach as above, calculate binomial probabilities as in Table 5.7 (but using now probabilities 0.469 for misses, 0.307 for bad misses, see below for the determination of these numbers), and reject the hypothesis that the chronology is wrong if the number of misses is improbably low. But we shall prefer a different approach which is less dependent on model assumptions.

For the 'long' Venus chronology, Ammisaduqa year 1, month I starts with syzygy number -8666 (we extended Goldstine's numbering of the new moons backwards beyond the year -1000). We now align Ammisaduqa 1 I with each of the 20000 new moons between the syzygy numbers -17000 and +2999, with the observed 30-day months trailing behind with the appropriate separations, and for each of these alignments we calculate the number of misses and bad misses; 20000 is an arbitrarily chosen large number. The results are shown in the following table.

# of all misses	# of cases	cumulative	%
2	1	1	0.01%
3	26	27	0.14
4	89	116	0.58
5	295	411	2.06
6	777	1188	5.94
7	1563	2751	13.76
8	2710	5461	27.30
9	3406	8867	44.34
10	3555	12422	62.11
11	3142	15564	77.82
12	2132	17696	88.48
13	1268	18964	92.82
14	623	19587	97.94
15	279	19866	99.33
16	83	19949	99.75
17	38	19987	99.94
18	12	19999	99.99
19	1	20000	100.00

# of bad misses	# of cases	cumulative	%
0	8	8	0.04%
1	68	76	0.38
2	369	445	2.22
3	1018	1463	7.32
4	2137	3600	18.00
5	3164	6764	33.82
6	3719	10483	52.42
7	3544	14027	70.14
8	2724	16751	83.76
9	1670	18421	92.11
10	951	19372	96.86
11	389	19761	98.81
12	170	19931	99.66
13	46	19977	99.89
14	21	19998	99.99
15	1	19999	99.99
16	1	20000	100.00

Table 5.8 Histogram for 20000 alignments of the 21 Ammisaduqa month-lengths.

Among the 20000 alignments, 19999 must be wrong. Thus, the probability for a *wrong chronology* to give 6 or fewer misses is about 5.94%, and to give 2 or fewer bad misses, is about 2.22%. The probability that the *best out of four wrong chronologies* attains 6 or fewer misses is $1-(1-0.0594)^4=0.22$, that it attains 2 or fewer bad misses is $1-(1-0.0222)^4=0.09$. These probabilities are not low enough to force a decision in favor of the -1701 chronology, even though the agreement of the month-lengths is comparable, in fact a shade better, than the average agreement of the LB control material.

From now on, we shall use the -1701 chronology as a working hypothesis, to be confirmed or rejected by further data. The discussion of the other Venus

chronologies, different from the four main ones, shall be postponed until Section 7.

We note that for the -1701 chronology the 21 New Year syzygies of Ammisaduqa show longitudes ranging from 355° to 48° , with a median of 26° .

There are a few texts that allow us to deduce month-lengths because they give the number of days between specified dates. One such text is CT 2,18, dated Ammisaduqa year 15 XII 30. Unfortunately, the text is somewhat garbled; C. B. F. Walker kindly collated the tablet, but several errors and at least one serious inconsistency remain (the text contains enough redundancy that errors show up, but it is not always possible to correct them). The text indicates that month V had 29 days; one part of the text seems to assume that the months VII, VIII had 29 and 30 days respectively, while another part supposes the opposite order. With the latter choice, the sequence of month-lengths from V to XII is compatible with calculations for the long chronology, with the sole exception of month X (with marginal visibility conditions, $\Delta h = 0.1$) which here and also otherwise is attested as a 30-day month.

Another such text is Di 199 (treated by K. van Lerberghe in his unpublished thesis), dated Ammisaduqa year 11 VIII 6. There are some uncertain readings, but it appears that month V had 30 days, and that among the months IV, VI, VI₂ and VII, two had 29 days and two 30 days. All this agrees with calculations for the long chronology.

Some uncertainties remain, and I did not use these two texts in the formal assessment of the evidence.

5.4.2. Some methodological remarks

How big sample sizes do we need to reach reasonably reliable conclusions? Should we use misses or bad misses for the statistical tests? We now discuss these issues somewhat more theoretically.

From the LB material we determined that for a correct chronology the probability of a miss (or bad miss) is about $p = 0.327$ (or 0.163). From the numbers in Table 5.8 we can calculate the corresponding probabilities for a wrong chronology, namely $q = 0.469$ (or 0.307 respectively). On the basis of these numbers p and q we now may estimate the number of observations needed to discriminate with given probabilities of error between a correct and a wrong chronology.

These calculations are only approximate; they are based on the remark that the counts of misses or bad misses are approximately binomial with parameters n and p , and hence approximately normal with mean np and variance $np(1-p)$ if the chronology is correct; if it is wrong, p is replaced by q .

Assume first that we are testing the hypothesis that a particular chronology is correct (i.e., we want to throw out a wrong chronology by rejecting the hypothesis; non-rejection means that we regard the situation as inconclusive). If we fix the probability of an error of the first kind (false rejection of a true hypothesis) to be α , and the probability of an error of the second kind (non-rejection of a false hypothesis) to be β , the minimum required sample size is approximately given by the solution n of

$$np + k_\alpha \sqrt{np(1-p)} = nq - k_\beta \sqrt{nq(1-q)},$$

that is

$$n = \left[\frac{\sqrt{p(1-p)}}{q-p} k_\alpha + \frac{\sqrt{q(1-q)}}{q-p} k_\beta \right]^2,$$

where k_α and k_β are the $1-\alpha$ and $1-\beta$ quantiles of the standard normal distribution (i.e. the values which are exceeded with probabilities α and β respectively).

Numerically, we obtain for misses

$$n = (3.30k_\alpha + 3.51k_\beta)^2,$$

and for bad misses

$$n = (2.57k_\alpha + 3.20k_\beta)^2.$$

Example: if $\alpha=0.05$, $\beta=0.5$, we obtain $n=29$ with misses, $n=18$ with bad misses. Generally, so long as $\alpha \leq 0.5$ and $\beta \leq 0.5$, we need on the average between 20% and 40% fewer observations with bad misses than with misses.

Assume now that we are testing the hypothesis that the chronology is incorrect (i.e. we want to confirm correctness of a chronology by rejecting the hypothesis), then the same formulas hold, with α and β interchanged, but the situation is nevertheless different. The problem is that typically more than one chronology is under consideration, and that we need quite low probabilities of errors of the first kind for the test to be conclusive. In the former situation this problem did not arise, since at most one of the tested chronologies can be correct. With the sample sizes currently at our disposal, we cannot achieve a low α unless we are willing to accept quite high probabilities of errors of the second kind (possibly $\beta > 0.5$), and k_β may be negative. Then tests based on misses may become preferable. For example, if $\alpha=0.0025$, $\beta=0.8$, then we need a sample size of about $n=47$ with misses, $n=50$ with bad misses; note that $\beta=0.8$ means that even when a chronology is correct, we shall reach a conclusion only in a lucky 1/5 of the cases tested.

Expressed somewhat differently, this means that when several chronologies are under consideration, we shall be able to affirm the correctness of any one of them with a reasonably high degree of confidence only if it agrees with calculation rather better than average.

The weakest aspect of the above calculations is the value of p (estimated from the LB material). Apart from that, it is not evident how well the binomial distribution approximates the number of misses. When we are testing the hypothesis that the chronology is correct, we have no other choice than to rely on the binomial, but when we are testing the hypothesis that the chronology is incorrect, we may alternatively use a nonparametric approach based on a large number of alignments (as in Table 5.8). As a matter of fact, the tests derived from the binomial distribution in this case give almost the same results, so the use of the latter can be justified *a posteriori*, though the binomial appears to give somewhat too optimistic results when extreme tail probabilities are concerned.

5.4.3. Ammiditana years 22-37

We are now using the long chronology as our working hypothesis, to be confirmed or rejected. For the last 16 years of Ammiditana 8 intercalations are attested. There is a surprising sequence of 4 consecutive intercalary years (25 to 28), and even if we delete the most unlikely of them (the curious month XI₂(!) in year 25), we are still slightly above the expected average of 7 intercalations in

19 years. So it is likely that we have the full pattern of intercalations for these years; at worst, one might be missing near the beginning or end of the segment.

If we put these last years of Ammiditana snugly in front of Ammisaduqa (taking 25 as a regular year), we obtain a median solar longitude of 29° and a range of 357° to 55° at the New Year syzygy for these 16 years.

If we insert an unattested intercalation in between (either a XII₂ in Ammiditana 36, or a VI₂ in Ammisaduqa 1, which would not interfere with the Venus or month-length data), these longitudes are shifted to a median of 5° and a range 328° to 27° .

We accept the latter choice since it results in an excellent fit for the month-lengths: among 13 attested 30-day months we have only 1 miss and no bad misses, while the former gives 9 misses, 6 of them bad. The probability that a wrong chronology gives 1 or fewer misses by chance is about 0.32%. (This number is found from a histogram analogous to Table 5.8.) Since we pick the better alignment among two, the agreement is significant only on a level of about 2 times 0.32% = 0.64%, but this is amply sufficient to confirm the correctness of the long chronology. (There is only one 30-day month before year 25, and it agrees with calculation for the -1701 chronology whether or not we treat year 25 as an intercalary year.)

5.4.4. Hammurapi 31 to Samsuiluna 11

This segment of 24 years contains 11 reasonably certain intercalations, again with a surprising sequence of four consecutive ones (Hammurapi 32A, 33A, 34A, 35U, 38U, 40U, Samsuiluna 3U, 5U, 8U, 9A, 11), while about 9 are expected, so it is likely that they are complete. There are 54 attested 30-day months. If we reckon backwards from Ammisaduqa 1 = -1701, then Samsuiluna 1 began in -1804, and if we let month I begin with lunation #-9942, we obtain 19 misses, 12 of them bad ones. The miss rates, $19/54=35\%$ and $12/54=22\%$, are above the NB values for a correct chronology (33%, 16%), but substantially below the values expected for a wrong one (47%, 31%). The probability that a correct chronology yields 12 or more bad misses in 54 trials is about 0.13. On the other hand, the probability that a randomly picked wrong chronology gives 19 or fewer misses is 0.054, but since we picked the better of the two feasible alignments for -1804, the latter number should better be doubled. Thus, this segment offers only inconclusive evidence with regard to chronology, and it does not by itself allow us to fix the date of Hammurapi astronomically, but it certainly does not contradict the long chronology.

The Ammisaduqa-Ammiditana data gave fewer misses and bad misses than the NB average, while the Hammurapi-Samsuiluna data are about 1 miss and 3 bad misses above it. This is well within chance fluctuations, but it is also possible that the higher number of bad misses has been caused by a misplaced intercalation.

Since it is conceivable that the traditional count (103 years) for the distance between the accession years of Samsuiluna and Ammisaduqa might be off by a few units, especially in view of our Rimsin findings (see Section 5.5), I checked also the neighboring years, but they do not give a better match.

For this alignment, the New Year syzygy longitudes range between 298° and 14° , with a median of 346° .

Thus, if the above matchings are correct, the median New Year syzygy longitude moved from 346° (Hammurapi-Samsuiluna) to 5° (Ammiditana) and to 26° (Ammisaduqa) between the years -1817 and -1680. Clearly, we would be happier with a more constant beginning of the year, but on the other hand, we saw that the Neobabylonian longitudes changed by a comparable amount in a similar time span (from 346° to 12° between -747 and -500).

5.4.5. Clocktime error?

To check on the possible influence of a clocktime error, some of the calculations were repeated with a two-hour clocktime difference (the elements were left the same, but the geographical longitude was changed to 30° west of Babylon). This increases all Δh -values by approximately 1° . The long chronology (Ammisaduqa 1 = -1701) then still gives the best fit, but the evidence in its favor is slightly weakened: the 21 month-lengths from Ammisaduqa's reign then give 6 misses, 5 of them bad ones, while Ammiditana's 13 month-lengths give 2 misses, one of them bad.

5.5. Month-lengths of Larsa: Rimsin years 1-23

The calendar of the second half of Rimsin's reign is peculiar and confusing (cf. F. R. Kraus, *ZA* 53(1953) 136-167). Note in particular that the years 34-60 seem to lack intercalations; the sole attested one is in Rimsin year 49 (Langdon PSBA 34 pl.X no.VII), and being unique, it might very well be a fluke. This may have consequences with regard to the relative chronology of the Larsa dynasty: if, for instance, Rimsin used a 12-month lunar year without intercalations during a substantial part of his reign, his regnal years would be slightly shorter, and the customary synchronism Hammurapi 30 = Rimsin 60 might lead to Hammurapi 1 = Rimsin 32, instead of Rimsin 31.

For the time being, this leaves us with the first half of Rimsin's reign; see the Appendix, Section 4, for the data. If we accept Hammurapi 1 = Rimsin 31, and reckon backward from Ammisaduqa 1 = -1701, we arrive at Rimsin 1 = -1877. There seem to be too few intercalations after year 18, and I arbitrarily inserted two in the years 21 and 24. For this chronology, the month-lengths match poorly (12 misses, 9 of them bad, out of 26 month-lengths from Rimsin years 1 to 23). This corresponds roughly to what one should expect from a random wrong match; the probability that a correct match gives 9 or more bad misses is only about 2%. There is a very good match three years later (Rimsin 1 = -1874), with 6 misses, 3 of them bad. The probability that a randomly chosen match gives 6 or fewer misses is about 0.65%, but since there is more than one year under consideration, and each year contains about 3 matches compatible with the seasons, the argument in favor of Rimsin 1 = -1874 is not decisive. It might very well be a statistical fluke, possibly caused by our arbitrary insertion of an intercalation in year 21; but on the other hand, the apparent shift of 3 years might be real and indicate some error in the counting of regnal years of the Hammurapi dynasty or of Rimsin, in addition to a shift caused by shorter years during Rimsin's reign, or perhaps even an error in the Hammurapi-Rimsin synchronism.

If we use a Bayesian argument and assume that each of the 11 years between -1882 and -1872 has equal prior probability 9% of being year 1 of Rimsin, then the posterior probabilities, given the 26 observed month-lengths, are 7, 5, 11, 9, 7, 2, 3, 4, 34, 14 and 4% respectively for these 11 years.

There is no good match corresponding to the supershort chronology (Ammisaduqa year 1 = -1517, plus or minus a few years).

For the most probable chronology (Rimsin 1 = -1874) the syzygy longitudes at New Year range from 335° to 19°, with a median of 1°.

5.6. Month-lengths of Ur III

Whiting furnished data from Drehem (Shulgi 40 to Ibbisin 2, 108 month-lengths, 13 of which have 29 days) and Umma (Amarsin 1 to Ibbisin 3, 60 month-lengths, 25 of which have 29 days), see the Appendix, Section 5. The intercalations for Drehem are complete; those for Umma are more than complete, but if one omits those marked as questionable by Whiting, one obtains a complete-looking pattern from Amarsin 1 to Shusin 7, containing 46 month-lengths.

The intercalations are obviously different in Drehem and Umma; unfortunately there is no documentary evidence linking the two calendars.

First, I aligned the Drehem and Umma data separately along the calculated sequence in 4000 consecutive positions, corresponding to Amarsin year 1 beginning anytime between -2213 and -1890.

I searched for pairs of alignments where Drehem and Umma would differ by not more than one month, and both would show a reasonably good fit. There was at least one promising simultaneous fit (Amarsin year 1 beginning in -2093, with lunation #-13516 for both Drehem and Umma).

At this point I should mention that month-lengths are not particularly well suited to correlate two calendars directly: the discrepancy rate between two independently observed sequences of crescents ordinarily will exceed the discrepancy rate between observation and calculation (that is, unless the clock-time error is larger than expected), and too few month-lengths will be simultaneously attested at both places. In our case, there are 14 months jointly attested, with 4 disagreements.

If we let Amarsin year 1 begin simultaneously in Drehem and Umma, we obtain a remarkably good agreement between the two calendars: during the 16 years from Amarsin 1 to Shusin 7, Drehem is one month ahead 4 times, Umma is one month ahead 3 times, and for the remaining 9 years both are in step.

If we now join the two lists, we get a total of 154 month-lengths (referring to a total of 140 different months). Among the 4000 alignments tried, the best match (49 misses) is out of season by 5 months. The second best (51 misses, 51/154=33%) is the already mentioned one, with Amarsin 1 beginning with lunation #-13516 in -2093.

In a more extended trial, 19 among 30000 alignments achieved 51 or fewer misses; thus the probability that in a single try a randomly chosen wrong chronology achieves 51 or fewer misses is about $19/30000=0.063\%$. Note that these numbers are similar to what the true match achieved for the 153 Neo- and Late Babylonian month-lengths (Table 5.5). The main difference is that the number of bad misses for Ur III (31/154=20%) is slightly higher than for the later texts (25/153=16%).

Amarsin's reign began about 399 years (plus minus 10 years) before Ammisaduqa's, that is about -2100, and we would probably be willing to accept a good fit of the month-lengths for any of about 30 years between -2115 and -2085. For each year, there are about 3 feasible beginnings (i.e. with a syzygy longitude between 325° and 45°, see Section 3), which makes about 90 possibilities to be

considered. The probability that the best agreement in 90 randomly tried chronologies gives 51 or fewer misses is about $1-(1-0.00063)^{90} = 0.055$.

These probabilities admittedly are not very reliable; the number 19 entering in their determination is too small to have statistically stabilized, and it could just as well have happened to be 14 or 24 instead of 19. But they are still small enough to give us at least a moderate degree of confidence in the correctness of the chronology.

The beginning of the year (i.e. the solar longitude at the New Year syzygy) then falls as follows:

Drehem (Amarsin 1 to Shusin 6, 15 years): median 355° , range 328° to 21° .

Umma (Amarsin 1 to Shusin 6, 15 years): median 0° , range 344° to 18° .

Drehem (Shulgi 40 to Ibbisin 3, 30 years): median 2° , range 328° to 41° .

These values are reassuringly close to the center of the feasible range and to the OB and NB values and ranges.

6. Eclipses

Schaumberger's discussion in AfO 17, p. 89ff., and in ZA 49, p. 50-58, makes it plain that the identification of the eclipses in Enuma Anu Enlil is far from unique. The most serious difficulty is that we do not know how much of the eclipse descriptions is fact and based on single, actually observed eclipses, and how much is schematic composition and learned speculation. Therefore, we do not give much weight to the following discussion. For the texts, see the articles by Schaumberger just cited and the references therein, and the recent (unpublished) thesis of F. Rochberg-Halton. The modern calculations are taken from Hiller and Neugebauer, *Erg. hefte zu den Astron. Nachrichten*, Band 8, No. 4 and Band 9, No. 2.

The chronology for Ur III postulated here (Amarsin year 1 = -2093) yields reasonably convincing identifications both for the patricide eclipse marking the end of Shulgi(?), and for the eclipse marking the end of Ibbisin.

The former occurred on III 14; it began in the first watch of the night and 'touched' the second, and the shadow moved from east 'above' to west 'below'.

This may be the total eclipse of -2094 July 25, which began at 19.6^h local time and ended at 23.2^h. The entrance and exit angles are with 73° and 285° are fairly close to east (90°) and west (270°).

In the Drehem calendar, the date corresponds to Shulgi's last year, 48 IV 13. The discrepancy in the month may indicate different intercalations in Ur and Drehem (with a somewhat late beginning of the year in Ur: 34° at New Year syzygy). The discrepancy in the day probably is meaningless, since Enuma Anu Enlil stylizes the eclipses to happen on the 14th day, never on the 13th. Apart from that, the discrepancy might also be explained by an early sighting of the lunar crescent ($\Delta h = -1.4^\circ$). The nearest eclipses giving a similarly good agreement occur in -2139 and -2018.

The eclipse marking the end of Ibbisin occurred on XII 14, beginning in the south in the first watch, leaving the north side free, and ending in the third watch.

This may be the partial eclipse (magnitude 7.6") of -2052 April 13-14, which began 21.4^h and ended 0.3^h. The entrance angle is 160°, agreeing well with the text (south = 180°). The date corresponds to Ibbisin's second last year 23 XII 13. The disagreement in the day may again be explained as an early sighting of the crescent (with $\Delta h = -1.5^\circ$). The nearest eclipses fitting equally well or better occur in -2106 and -2030.

The Babylon eclipse, presaging the end of the First Dynasty of Babylon, is interesting. The text appears to mention a (solar) eclipse 14 days after the lunar eclipse. Schaumberger took this to be a mere warning for the astrologer to be on the lookout. The interpretation of the passage is far from clear; possibly the text does not refer to a solar eclipse at all, but merely gives a brief hint on how to predict the lunar eclipse from some (unclear) event observed on the (preceding) 28th. I read and interpret the crucial sentence as follows: *ina ud-28-kam igi-ma an-mi gur-ru-ub sar-ma sa₅-ma*, 'On the 28th you observe and an eclipse is close by; it begins and makes full (its time)'. But since the interpretation of the omen hinges on the temporal closeness of the second eclipse (it seems to deduce the closeness of the destruction of Babylon from it, note the repetition of the word *qurru_b*), there might be more to it, and we believe the omen refers to a genuine pair of eclipses.

Thus, we have to look for an eclipse pair with the following characteristics. The lunar eclipse is on XI 14, beginning on the south side 'above' in the morning watch and clearing on the west side 'below'; the eclipsed moon is seen together with the sun and sets before the end of the eclipse. The solar eclipse on the 28th is visible from the beginning to the end(?).

Between -1950 and -1350 there are only three eclipse pairs that more or less fit:

- 1712 Jan. 8 and 22,
- 1658 Feb. 9 and 23,
- 1531 April 14 and 29.

By chance, each of them matches a Venus chronology: Ammišaduqa 1 beginning in -1757, -1701 and -1581 respectively, and Babylon I ending in -1706, -1650 and -1530 respectively.

The first possibility fits reasonably well; the moon sets in the very middle of the eclipse at a maximal phase of 5.9". The beginning of the year is somewhat early (328°), which however is acceptable for an intercalary year with a XII₂.

The second pair may fit even better. The lunar eclipse begins at 4.9^h local time and ends at 7.0^h, 0.1^h after the calculated sunrise/moonset. It reaches only a magnitude of 3.7"; the entrance and exit angles are 164° and 236° respectively. The solar eclipse reaches a largest phase of 9.2" at 11.9^h (noon).

The fit for the third is the poorest: it gives an extremely late beginning of the year (the following New Year syzygy would be at 52°). The eclipse begins only about 1/2 hour before sunrise, and thus there is not enough time for it to clear up. The time interval between the two eclipses disagrees (15 instead of 14 days).

The Babylon eclipse thus appears to furnish some further support for the long chronology.

7. Comprehensive assessment of the evidence

In this section, we summarize and combine our findings. Several, methodologically distinct, statistical approaches are possible, and we first discuss the approach briefly outlined in the Introduction. With this approach, we begin by picking a favorite chronology on the basis of historical arguments and part of the astronomical data, and we then use a hit-or-miss approach with the remaining data to test its correctness.

We only consider chronologies roughly compatible with the Venus Tablet (but this assumption shall be tested afterwards). The current consensus among historians regards solutions with Ammisaduqa year 1 after -1581 as unlikely, and only few scholars seem to be inclined to go much above -1701, so we shall, at least in the beginning, argue on the basis of the four main chronologies (Ammisaduqa year 1 = -1701, -1645, -1637, or -1581) only.

The Venus Tablet evidence agrees well with the -1701 solution, shows systematic deviations for the next two -- they are statistically significant on the 1%-level -- and it may or may not agree with the -1581 solution (the conclusion depends somewhat on the data selection, much of the support for this chronology seems to derive from the most corrupt final years of the Venus Tablet). Compare in particular Tables 4.3.a, 4.3.b and 7.1.

The Ammisaduqa month-lengths agree well with -1701, but show discrepancies for the other three chronologies. If we work with the misses, as we shall do, these discrepancies are statistically significant on the 2% level. Although the agreement for -1701 is quite good and even a shade better than what we would expect for a correct solution, it is not significantly better than the agreement we would expect for the best out of four randomly chosen wrong chronologies.

We now use the Ammiditana month-length data to test whether the good agreement for -1701 could have been obtained by chance. The test turns out to be significant on the 1% level and thus shows that the -1701 solution in all likelihood is the correct chronology. The Hammurapi-Samsuiluna data add little to this conclusion: the agreement is a little bit worse than expected for a correct chronology, but better than expected for a wrong chronology. For details see Sections 5.4.1, 5.4.3 and 5.4.4.

CHRONOLOGY Year 1 I		SEASON Year 16	VENUS		MONTH-LENGTHS years 1-16			
Year	syz#	L	38	31	misses		bad m.	
-1976	-12067	34°	.050	.114	10	.11	7	.44
-1920	-11375	16	.039	.0034	13	.006	6	.11
-1912	-11276	18	.0000	.0003	10	.11	6	.11
-1856	-10584	1	.25	.74	14	.002	10	.0008
-1800	-9892	343	.0013	.0000	10	.11	6	.11
-1792	-9793	345	.0013	.021	7	.56	4	.46
-1736	-9101	326	.94	.066	9	.22	5	.25
-1765	-9457	43	.17	.017	7	.56	3	.69
-1757	-9358	44	.0006	.023	9	.22	8	.014
-1701	-8666	26	.41	.86	6	.73	2	.88
-1645	-7974	9	.0010	.0000	13	.006	9	.004
-1637	-7875	10	.0001	.0045	12	.018	8	.014
-1581	-7183	353	.56	.024	12	.018	7	.044
-1525	-6491	335	.0001	.0000	9	.22	4	.46
-1517	-6392	337	.18	.98	6	.73	4	.46
-1538	-6649	54	.0000	.0003	13	.006	8	.014
-1482	-5957	37	.047	.12	7	.56	3	.69
-1426	-5265	19	.060	.0028	11	.049	5	.25
-1418	-5166	20	.0000	.0000	8	.37	4	.46
-1362	-4474	3			12	.018	7	.044

Table 7.1. The Venus chronologies: minimum rejection levels based on the Venus and month-length data from the time of Ammisaduqa. In the column CHRONOLOGY the year and the syzygy number of Ammisaduqa 1 I are given. The column SEASON contains the solar longitude for the New Year syzygy of Ammisaduqa year 16 (this gives the median longitude for Ammisaduqa's reign). The column VENUS contains the minimum rejection levels for Wilcoxon's test for shift; a large number (above .1) indicates a good fit, a small number (below .01) suggests that the chronology should be rejected. The tests were done twice: with 38 (sometimes 41) dates, and with 31 dates (in particular excluding years 19 to 21). The column MONTH-LENGTHS gives the number of misses and bad misses for the 21 attested 30-day months in the years 1-16, together with the probability that a correct chronology would give this or a larger number of misses (based on the frequency of misses and bad misses for Neo- and Late Babylonian data); see Section 5.4.1.

If we start with a wider historically feasible range, we still end up with -1701, but the conclusion is somewhat less secure. If we allow all 20 Venus chronologies between -1976 and -1362 for competition, and submit them to the same screening process, then some 8 choices remain viable after checking with the Ammisaduqa month-length data (namely -1976, -1792, -1765, -1757, -1736, -1701, -1517, -1482). The most promising among them are -1701 and -1517, and both are about equally good. The former agrees better with the Ammiditana data (only 1 miss in 13) than the latter (4 misses in 13); both agreements are in fact better than what we would expect from the NB control material. The probability that the best among 8 randomly chosen wrong chronologies fits the Ammiditana data as well or better than the -1701 solution is about $1 - (1 - 0.0064)^8 = 0.05$, so we decide again in favor of -1701, but with a lesser degree of confidence. While -1517 remains an astronomically feasible solution, it fits only about as well as the best among ²⁰four randomly chosen wrong chronologies is expected to fit.

The above conclusion -- that the good agreement for the -1701 chronology is not a chance effect -- is practically independent of model assumptions, since the crucial probabilities were determined by a nonparametric method. It has several important consequences:

- (1) it confirms the validity of the Venus Tablet data (and of the data screening process);
- (2) it confirms the validity of the astronomical calculations (i.e., it shows that the clocktime error cannot be too bad, probably below two hours, cf. Section 5.4.5);
- (3) it confirms the validity of the month-length data (i.e., that during Babylon I the 30-day dates ordinarily represent genuine last days of true lunar months).

The point is, that if any of these assumptions had been severely violated, the good agreement with the calculated month-lengths would have been thrown back to an essentially random one.

Some margin of error remains -- if one rejects a hypothesis on the 5% level, one expects to do so wrongly in 5% of the cases. There are two slightly discordant notes. The first is the surprisingly big shift in the median beginning of the year. (Hammurapi's and Samsuiluna's years began on the average 12 days before the spring equinox, Ammiditana's around the equinox, and Ammisaduqa's 27 days after the equinox.) This may be due to a most haphazard intercalation practice (note the 4 consecutive intercalations during Hammurapi's reign that move the beginning of the year forward by about 72 days). By the way, with the -1517 chronology we would have to admit an even larger shift in the opposite direction.

The second is that Rimsin's month-lengths do not seem to match the traditional synchronism Hammurapi 1 = Rimsin 31. There is a good match if Rimsin is moved forward by three years. Part of this shift, if it is real, may have been caused by Rimsin's using a lunar(?) calendar with shorter years during the latter part of his reign, compare Section 5.5. The matter clearly deserves further investigation.

We now discuss another statistical approach. If, instead of a hit-or-miss approach, we would like to assess the differential strength of evidence in favor of the various Venus chronologies, so-called Bayesian methods are more germane. They also provide a somewhat more convenient way for combining and summarizing evidence from different sources (but are somewhat more dependent on model assumptions).

If we assume that each of the 19 or 20 Venus chronologies of Table 7.1 is a priori equally likely, then knowledge of the Wilcoxon tests performed on the Venus Tablet data changes these probabilities to

$$p_{Vs}(i) = \frac{e^{-w_i^2/2}}{\sum_i e^{-w_i^2/2}},$$

where w_i is the value of the normalized Wilcoxon test statistic (using the data set containing 31 items).

The month-lengths from Ammisaduqa's reign, considered alone, change the probabilities to

$$p_{As}(i) = C \left(\frac{p}{q} \right)^{m_i} \left(\frac{1-p}{1-q} \right)^{n-m_i},$$

where the constant C in this and in the following formulas is chosen such that the terms add up to 1, $p=50/153$ is the estimated probability of a miss for a correct chronology, $q=0.47$ the same for an incorrect chronology, m_i is the number of misses, and n is the total number of month-lengths under consideration (for Ammisaduqa $n=21$).

This formula was derived from the assumption that the number of misses follows a binomial distribution. This is not an entirely trustworthy approximation, and the reliance on the Neo-Babylonian value of p is questionable, but it would seem difficult to come up with something better.

For Ammiditana and Hammurapi-Samsuiluna, the formulas get more complicated, since then for each year two or three matchings should be tried (corresponding to a beginning of the year that is a month earlier or later). If, for simplicity, we assign equal probability to each of these possibilities, we must replace the right-hand side of the preceding formula by its average over the two or three possible cases.

The combined month-length evidence then can be expressed by

$$p_{ml}(i) = Cp_{As}(i)p_{Ad}(i)p_{HS}(i),$$

and the total, combined evidence by

$$p_{tot}(i) = Cp_{Vs}(i)p_{ml}(i).$$

These numbers are collected in Table 7.2. Negative w -values indicate that the Venus phenomena are early on the average for that particular chronology. In the case of Ammiditana and Hammurapi-Samsuiluna, we only give the smallest number of misses among the two or three feasible beginnings of the year, since the probabilities are predominantly determined by these minimal values. By an oversight, the Wilcoxon test statistics for the -1362 chronology were not computed.

YEAR	VENUS		MONTH-LENGTHS						TOTAL
	Ammisaduqa		Ammisaduqa		Ammiditana		Hammurapi-Samsuiluna		
	<i>w</i>	<i>p_{VS}</i>	<i>m</i>	<i>p_{AS}</i>	<i>m</i>	<i>p_{Ad}</i>	<i>m</i>	<i>p_{HS}</i>	<i>p_{mt}</i>
-1976	1.58	.07	10	.018	6	.019	21	.043	.0015
-1920	-2.93	.003	13	.003	6	.017	23	.026	.0001
-1912	3.63	.0003	10	.018	6	.017	22	.031	.0010
-1856	-0.33	.24	14	.002	6	.023	25	.011	<10 ⁻⁴
-1800	-4.65	<10 ⁻⁵	10	.018	8	.009	25	.005	<10 ⁻⁴
-1792	2.31	.02	7	.112	3	.106	24	.008	.0093
-1736	-1.84	.05	9	.034	6	.023	20	.077	.0059
-1765	-2.39	.01	7	.112	5	.032	23	.016	.0057
-1757	2.28	.02	9	.034	4	.058	21	.043	.0093
-1701	-0.18	.24	6	.205	1	.306	19	.139	.8674
-1645	-4.84	<10 ⁻⁵	13	.003	5	.032	23	.014	.0001
-1637	2.84	.004	12	.006	8	.005	22	.038	.0001
-1581	-2.26	.02	12	.006	5	.030	24	.009	.0001
-1525	-5.41	<10 ⁻⁶	9	.034	9	.004	24	.014	.0002
-1517	-0.02	.25	6	.205	4	.065	21	.045	.0590
-1538	3.62	.0003	13	.002	4	.054	24	.014	.0002
-1482	1.56	.07	7	.112	3	.096	25	.005	.0051
-1426	-2.99	.003	11	.010	4	.054	21	.070	.0038
-1418	4.29	<10 ⁻⁴	8	.061	6	.019	18	.251	.0297
-1362	NA	NA	12	.006	5	.030	19	.144	.0023
									NA

Table 7.2. Relative likelihoods of the Venus chronologies.

It can be seen from Table 7.2 that in each individual column, the -1701 chronology is among the three most likely, and that ultimately, it is 15 times more probable than the runner-up (-1517). The combined evidence gives probability 0.93 to the -1701 chronology. This value is comparable to the 0.95 confidence level we had obtained for it with the first approach (but the two concepts have a different interpretation).

Similar calculations were performed for the Ur III data. If we reckon backward from Ammisaduqa, we obtain that Amarsin year 1 should begin in -2100. All feasible beginnings of Amarsin 1 between the years -2115 and -2085, that is, with New Year syzygy longitudes between 315° and 45°, were checked (there are 98 of them). The likelihoods

$$p(i) = C \left(\frac{p}{q} \right)^{m_i} \left(\frac{1-p}{1-q} \right)^{n-m_i}$$

were calculated for Drehem ($n=108$) and for Umma ($n=46$) separately, and then combined. The following Table 7.3 lists the seven most likely matchings among the 98 for Amarsin 1 month I; incidentally, the 3 best separate matches for

Drehem and Umma among the 98 are contained in this list.

Syz #	L	Year	Drehem		Umma		Total	
			<i>m</i>	<i>p</i>	<i>m</i>	<i>p</i>	<i>m</i>	<i>p</i>
-13516	355°	-2093	38	.60	13	.22	51	.939
-13701	10°	-2108	43	.03	14	.12	57	.025
-13725	30°	-2110	41	.10	16	.04	57	.025
-13640	346°	-2103	48	.001	13	.22	61	.002
-13764	337°	-2113	42	.05	19	.01	61	.002
-13529	337°	-2094	45	.01	17	.02	62	.001
-13628	335°	-2102	45	.01	17	.02	62	.001

Table 7.3. Relative likelihoods of the Ur III matchings.

Note that the -2093 date is the most likely both for Drehem and for Umma, and it is about 40 times more likely than the next best choices (-2108, -2110) in this 31-year interval. The 7-year shift points in the same direction as the putative 3-year shift for Rimsin, and the eclipse evidence seems to agree nicely (cf. Section 6), even if I do not dare to assign it any quantitative statistical weight.

The supershort chronology (-1517) does not agree well with the Ur III month-lengths. The best match (-1927) in the corresponding 31-year range from -1931 to -1901 has *m* = 57 misses and is 11 years early, if we reckon back from Ammisaduqa.

Abbreviations

- ACT O. Neugebauer, *Astronomical Cuneiform Texts*, 3 vols., London (1955).
- AHW W. von Soden, *Akkadisches Handwörterbuch*, Harrassowitz, Wiesbaden (1965-1981).
- LAS S. Parpola, *Letters from Assyrian Scholars to the Kings Esarhaddon and Assurbanipal*, Alter Orient und Altes Testament, 5/1, Verlag Butzon & Bercker Kevelaer, Neukirchen-Vluyn (1970).
- LBAT A. J. Sachs, *Late Babylonian Astronomical and Related Texts*, Brown University Press, Providence RI (1955).
- LFS S. Langdon, J. K. Fotheringham and C. Schoch, *The Venus Tablets of Ammizaduga*, Oxford University Press, London (1928).
- PD³ R. A. Parker and W. H. Dubberstein, *Babylonian Chronology 626 B.C.-A.D. 75*, 3rd ed., Brown University Press, Providence RI (1956).
- PVN P. V. Neugebauer, *Astronomische Chronologie*, 2 vols., Berlin und Leipzig (1929).
- RMA R. C. Thompson, *The Reports of the Magicians and Astrologers of Nineveh and Babylon*, Luzac and Co., London (1900).
- RP E. Reiner and D. Pingree, *The Venus Tablet of Ammisaduqa*, Bibliotheca Mesopotamica 2,1, Malibu CA (1975).
- SSB F. X. Kugler, *Sternkunde und Sterndienst in Babel*, 2 vols. + Erg.hefte, Münster (1907-35).

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APPENDIX

A-1. Neo- and Late Babylonian month-length data

The following list contains 155 month-lengths collected by A. Sachs and E. Leichty from Neo- and Late Babylonian economic-administrative texts. The Leichty material is from unpublished tablets with British Museum numbers from BM 49164 to 71858.

All texts are dated on the 30th of the month, and so attest a 30-day month, with four exceptions, where 29-day months are positively attested. The syzygy number (Syz #) agrees with Goldstine's numbering of the new moons; it and Δh_1 , Δh_2 refer to the beginning of the month in question, Δh_3 , Δh_4 to its end, giving the values of the calculated visibility criterion on the day before, and on the day of, the theoretical first visibility of the crescent. Agreement or disagreement with Huber's calculated month-length are indicated by + or - respectively in column H. If a discrepancy can plausibly be explained by a low Δh -value, the value in question is marked by an exclamation mark. Then, and also for all values $|\Delta h| < 1$, the difference Δ in azimuth and the altitude h for that particular sunset are given.

A star (*) in column H indicates that use of the LFS-criterion (cf. Table 5.1) would reverse the visibility condition. Column PD gives the agreement/disagreement according to the 3rd edition of Parker-Dubberstein (only for the Sachs data).

For the earliest two entries in the list the intercalation pattern is not sufficiently certain to allow a definite identification of the date.

Source	Date	Syz #	Δh_1	Δh_2	Δh_3	Δh_4	Δ	h	H	PD
<i>Shamash-shum-ukin</i>										
BM 40577	20 V	4372	-8.5	3.4	-3.8	7.6			+?	
<i>Kandalanu</i>										
TuM 2/3 67	14 XII	4553	-9.2	3.6	-2.2	9.8			+? +?	
<i>Nabopolassar</i>										
UET 4 56	2 II	4666	-8.3	4.0	-2.7	8.9			+	+
NCBT 310 (Goetze)	6 XI	4725	-7.4	3.2	-3.2	8.1			+	+
BM 49808	6 XII	4726			-10.0	1.6!	-1.3	11.9	-	
BM 51337	11 II	4778	-10.9	0.3	-5.9	4.4	1.7	10.6	+	*
GCC 2 70	12 VIII	4796	-7.0	2.5	-2.2	8.6			+	+
BM 50093	17 I	4851	-5.1	5.8	-1.1	10.2			+	
BM 52617	18 IV	4866	-5.6	5.4	-1.2	10.4			+	
BM 49395; BM 55832	20 VIII	4895	-5.4	1.9	-4.0	4.9			+	
<i>Nebuchadnezzar</i>										
AnOr 8 1	0 IX	4909	-5.7	3.6	-1.7	10.5			+	+
BM 49673	2 I	4925	-10.8	2.9	-1.4	12.7			+	+
BM 54169	3 I	4938	-9.8	3.2	-1.0	12.6			+	

Source	Date	Syz #	Δh_1	Δh_2	Δh_3	Δh_4	Δ	h	II	PD
BM 55816	3 VII	4944	-2.5	6.9	-1.0	9.2			+	
BM 56776	7 IX	4996	-5.5	7.8	-9.1	4.7			-	
BM 49556	8 IX	5008	-1.1!	11.6	-4.4	8.7	-10.1	8.2	-	
YOS 17 334	11 VI	5042	-4.8	6.3	-0.2	10.7	-15.1	7.8	++	+
BM 49439	11 IX	5045	-1.1!	8.3	-7.	2.2	-5.1	8.9	-	
BM 49487	12 I	5050	-1.3!	11.8	-6.4	6.7	-2.8	8.9	-	
YOS 17 330	12 X	5059	-4.6	5.0	-3.0	7.4			+	+
YOS 17 218	14 II	5075	-4.4	6.8	-0.3	11.7	-10.0	9.0	+	+
YOS 17 67; Moore Mich.29	14 XII ₂	5086	-8.5	2.6	-4.8	6.2			+	+
YOS 17 162	18 I	5124	-10.2	3.7	-1.6	11.2			+	+
BM 61428	20 IV	5151	-11.3	0.9	-2.5	8.4	-3.5	11.1	+	
BM 55843	23 III	5187	-6.6	4.0	-1.0	9.8			+	
AnOr 8 13	28 IX	5255	-8.3	0.7	-4.4	5.8	-11.0	9.8	+	+
BM 57517	33 VII	5315	-6.1	3.6	-8.6	0.3!	-6.1	10.1	-*	
GCC 1 193	34 VI	5327	-0.2!	9.3	-4.3	4.4	-7.8	9.4	-	-
Moore Mich.59	34 VIII	5329	-0.0!	10.2	-5.5	5.5	-4.4	10.0	-	-
Str.Nbk.274	34 X	5331	-11.8	0.3	-5.1	8.8	-4.2	10.4	+	-
TuM 2/3 127	35 I	5334	-1.5!	11.6	-7.3	5.1	-6.5	8.2	-	-
BM 62966	36 IV	5349	-10.4	1.1	-4.1	5.6			+	
GCC 1 156	37 V	5363	-1.3!	8.3	-5.4	2.0	-4.0	8.8	-	-
VS 6 49	40 VIII	5402	-5.1	4.7	-1.5	10.4			+	+
GCC 1 105	40 XI	5405	-0.6!	11.5	-6.2	5.4	-10.7	8.6	-	-
BM 56746	42 IV	5423	-5.2	4.0	-2.6	5.9			+	
<i>Amel-Marduk</i>										
GCC 2 79	0 X	5442	-0.8!	13.2	-4.7	9.5	-7.8	8.8	-	-
BM 40746	1 II	5446	-4.3	7.9	-8.4	2.2!	-1.3	12.6	-	-
GCC 2 78	1 IV	5448	-4.1	5.3	-3.1	5.3			+	+
<i>Nergal-shar-usur</i>										
Evetts Nerigl.27	1 VIII	5477	-6.1	3.3	-1.9	8.0			+	+
Ev.Ner.41=BM 63960	2 VIII	5489	-6.6	3.3	-1.6	8.4			+	+
BM 63305	3 VI	5499	-2.1	11.5	-6.8	5.4			-	
BM 54602	3 X	5503	-7.7	2.4	-3.8	6.4			+	
<i>Nabunaid</i>										
Str.Nbnd.17	0 XII	5518	-9.6	1.1	-6.6	4.2			+	+
Str.Nbnd.28; BM 62953	1 II	5520	-3.3	7.5	-0.1	11.0	-8.5	9.4	+	+
BM 63955	1 VIII	5526	-4.3	7.0	-7.1	3.6			-	
GCC 1 403	1 XII	5530	-1.4!	10.6	-8.2	3.4	0.3	9.0	-	-
BE 8 42	2 VI	5537	-6.2	3.6	-9.1	0.0!	-8.6	9.4	-*	+
BM 56894	3 III	5546	-8.1	2.7	-5.1	5.2			+	
YOS 6 60; GCC 1 397	3 VI	5549	-7.3	1.2	-3.1	5.7			+	+
BM 62734	3 VIII	5551	-6.8	1.3	-3.4	6.5			+	
Str.Nbnd.160; BM 58270	4 V	5561	-6.7	1.8	-3.3	4.7			+	+
Str.Nbnd.165	4 VI	5562			-0.6	7.6	-4.9	9.4	+	+
Moore Mich. 8	4 IX	5565	-4.5	5.5	-0.1	12.3	-4.7	9.9	+	+
BM 57007	5 II	5570	-5.3	8.5	-10.1	2.7			-	
Str.Nbnd.194	5 VI	5574	-2.8	5.4	-0.4	7.3	-5.2	9.5	+	+
Str.Nbnd.200=BM 60073	5 VIII	5576	-6.1	0.6	-6.4	1.8	-6.6	10.4	+	+
TuM 2/3 85	6 IV	5584	-8.7	4.0	-0.4	10.9	-6.0	9.4	+	+
YOS 6 167	6 VI	5586	-4.3	4.7	-0.7	7.5	-5.0	9.3	+	+
BM 64156	6 XII	5592	-11.0	0.9	-4.7	8.1	-7.5	10.5	+	

Source	Date	Syz #	Δh_1	Δh_2	Δh_3	Δh_4	Δ	h	H	PD
YOS 6 137	7 IV	5597	-7.0	4.9	-8.4	0.8!	-5.8	10.6	-	+
BM 61196	7 VI	5599	-3.5	5.2	-0.9	7.7	-6.8	8.9	+	
BM 57766	7 VII	5600			-7.5	0.1!	-10.4	9.4	-	
BM 61362	7 XII	5605	-8.1	3.4	-2.9	9.2			+	
Str.Nbnd.301	8 V	5610	-5.7	4.6	-7.9	0.1!	-6.1	9.9	-*	+
Str.Nbnd.310	8 X	5615	-6.1	4.6	-1.6	9.4			+	+
Str.Nbnd.395	9 XII	5629	-9.6	2.2	-4.8	6.3			+	+
BM 54039;BM 56876	10 I	5630			-0.9	10.1	-1.0	9.5	+	
YOS 6 194	10 V	5634	-6.0	2.9	-2.6	6.4			+	+
GCC 1 299	11 IV	5646	-7.1	1.2	-4.9	2.9			+	+
Str.Nbnd.578	11 XII	5654	-0.3!	13.3	-5.5	7.4	-2.5	10.0	-	-
BM 69013	12 IV	5658	-7.8	1.1	-5.5	2.4			+	
YOS 6 155;BM 62516	12 IX	5663	-9.4	1.2	-2.0	11.5			+	+
BM 62459	13 II	5669	-7.7	4.4	-0.8	10.1	-0.4	9.6	+	
Str.Nbnd.710=BM 60765	13 IV	5671	-6.5	2.3	-5.6	2.1			+	+
BM 56496	13 X	5677	-0.2!	12.6	-4.8	8.8	-7.4	9.4	-	
BM 67036	13 XI	5678			-9.5	4.4			-	
BM 70574	14 IV	5683	-0.6!	10.3	-7.3	1.5	-5.1	9.4	-	
Str.Nbnd.809=BM 60533	14 VIII	5687	-3.8	6.1	-9.1	0.4!	-14.0	8.7	-	+
BM 66129	15 II	5693	-13.0	0.4	-3.4	9.9	2.7	10.6	+	
BM 56886	15 IV	5695	-7.6	4.4	-2.5	9.0			+	
BM 64968	15 VI	5697	-9.1	0.4	-6.8	3.3	-17.4	7.7	+	
Str.Nbnd.915	15 IX	5700	-8.7	0.4	-4.7	5.1	-14.5	8.6	+	+
Str.Nbnd.994	16 VIII	5712	-9.7	0.0	-4.6	5.4	-14.3	8.2	+	-
BM 64984	16 XII	5716	-4.6	6.1	-0.6	10.6	2.6	9.6	+	
BM 60844	17 VI	5722	-6.6	6.0	-10.5	0.5!	-17.9	7.6	-	
<i>Cyrus</i>										
BM 62951	0 XII	5728	-4.4	5.9	-1.7	8.8			+	
Str.Cyr.66	2 VII	5748	-5.4	5.9	-8.1	2.6!	-11.3	11.7	-	-
Str.Cyr.114	3 III	5756	-3.4	7.2	-1.5	9.2			+	+
YOS 7 33	3 XII ₂	5766	-5.1	8.0	-10.6	2.0!	-5.8	11.9	-	-
BM 61330	4 II	5768	-4.5	7.1	-0.9	10.2	-10.6	8.2	+	
BM 64046	4 IV	5770	-8.3	1.5	-5.3	4.0			+	
BM 63442	4 VIII	5774	-1.8	7.6	-6.6	3.1			-	
Str.Cyr.195	5 III	5781	-2.9	9.5	-9.1	1.7!	-12.3	10.5	-	+
YOS 7 50	5 VII	5785	-5.8	1.9	-3.2	4.7			+	+
Str.Cyr.204	5 VIII	5786			-1.0	7.9			+	+
YOS 1 46	5 IX 29	5787			-7.6	2.2			+	+
BM 55869;BM 67071	5 XII	5790	-10.0	3.6	-0.9	13.4	-5.7	9.0	+	
BM 55977	6 III	5793	-9.9	3.8	-1.6	11.2			+	
BM 59650	6 XII	5802	-4.3	8.2	-9.9	3.4			-	
YOS 7 64	7 VI	5809	-6.9	1.6	-3.3	4.5			+	+
BM 64838	7 VIII	5811	-1.8	5.9	-1.3	7.2			+	
BM 55913;BM 61373	8 I	5816	-8.6	4.1	-0.9	12.6	-6.0	8.9	+	
Str.Cyr.315	8 V	5820	-10.2	0.6	-2.8	7.4	-6.2	10.4	+	+
YOS 7 94;Str.Cyr.329	8 XII	5827	-4.3	6.7	-11.3	0.1!	-6.3	9.8	-*	+
TCL 13 145	9 III 29	5830	-12.2	0.2!	-4.1	8.5	-4.4	10.2	-*	+
<i>Cambyses</i>										
VS 4 69;BIN 1 113	1 I	5841	-7.7	3.3	-3.3	8.0			+	+
TCL 13 147	1 III	5843	-8.6	2.5	-1.9	9.1			+	+

Source	Date	Syz #	Δh_1	Δh_2	Δh_3	Δh_4	Δ	h	II	PD
TCL 13 148	1 V	5845	-5.2	4.3	-0.5	9.5	-5.8	9.4	+	+
YOS 1 48	1 X	5850	-2.2	10.5	-7.2	5.0			-	-
Str.Camb.104;BM 56762	2 II	5854	-3.8	7.1	-9.6	0.7!	-1.3	11.1	-	-
Str.Camb.137	2 XI	5863	-0.8!	12.9	-5.5	7.7	-9.3	8.5	-	-
Str.Camb.174	3 VI	5870	-6.8	0.2	-6.4	0.9	-7.2	9.9	+	+
YOS 1 49	3 X 29	5875	-10.1	3.6	-14.2	0.1	-6.1	9.9	+	* -
YOS 7 137	3 XII	5877	-4.7	9.0	-9.5	3.5			-	-
Str.Camb.244	4 VI	5883	-0.8	7.9	-0.6	9.2	-11.6	8.2	+	+
YOS 1 50	5 I	5890	-4.4	9.6	-8.1	5.3			-	-
Str.Camb.287	5 VI	5895	-0.8	8.1	-1.3	8.0	-12.0	8.1	+	+
TCL 13 169	5 X	5899	-0.1!	12.1	-4.2	8.5	-11.9	8.8	-	+
S.C.305;YOS 1 51;BM57662	6 I	5903	-4.0	9.9	-7.1	6.1			-	-
TCL 13 175	6 II 29	5904			-9.8	1.6			+	+
TCL 13 176	6 III	5905			-3.9	6.3			+	+
YOS 7 192	7 III	5917	-7.1	5.6	-10.7	0.2!	-6.7	9.9	-	* +
BM 61517	7 V	5919	-6.0	4.4	-3.3	7.6			+	
Str.Camb.392	7 X	5924	-7.7	2.5	-4.0	6.8			+	+
Str.Camb.395	7 XI	5925			-10.9	0.1!	2.1	10.4	-	* +
<i>Darius I</i>										
YBC 3800	0 XII ₂	5939	-7.8	2.9	-3.7	7.3			+	+
BM 65080	3 XII	5976	-9.1	3.1	-3.4	8.4			+	
Str.Dar.195	5 XII ₂	6001	-4.9	9.3	-9.5	4.4			-	-
BM 70903	6 III	6004	-7.0	5.1	-2.2	9.2			+	
Str.Dar.205	6 VI	6007	-3.8	4.8	-0.6	7.8	-6.7	9.1	+	+
BM 56862	8 III	6028	-10.3	3.7	-0.8	13.1	-8.3	8.7	+	
Str.Dar.241	8 X	6035	-3.9	4.8	-2.8	7.3			+	+
AfO 19 p78b 30	15 IV	6116	-6.3	3.4	-3.3	5.1			+	+
Str.Dar.430	16 VI	6130	-4.7	4.1	-4.2	5.1			+	+
BM 65730	18 III	6152	-7.1	4.8	-0.6	11.6	-6.8	9.1	+	
BM 57275	18 V	6154	-6.6	4.5	-2.3	10.4			+	
BM 65323	19 II	6163	-6.6	4.2	-1.7	9.8			+	
Str.Dar.521	21 I	6187	-8.5	2.5	-4.5	6.2			+	+
BM 61769	21 VIII	6194	-2.6	9.6	-5.3	6.4			-	
BM 64566	22 V	6203	-8.0	1.5	-6.2	3.5			+	
BM 61270	23 VIII	6219	-3.4	5.6	-7.8	1.1!	-4.5	11.1	-	
Str.Dar.572	23 IX	6220			-4.4	6.7			+	+
BM 61891	25 VI	6242	-7.2	1.7	-2.9	5.4			+	
BM 46925	36 V	6377	-0.1!	12.7	-6.3	5.3	-14.5	8.1	-	* +
<i>Xerxes</i>										
VS 4 193	1 VIII	6392	-0.3!	13.5	-3.6	8.9	-16.5	7.3	-	-
<i>Artaxerxes I</i>										
VS 3 189	22 XI	6915	-6.4	3.8	-3.7	7.6			+	+
BE 9 26;CBS 12892	31 III	7018	-10.3	2.3	-1.0	10.9			+	+
<i>Antigonos</i>										
BM 67402	6 VII	8531	-5.4	2.6	-2.4	5.8			+	
<i>Seleucid Era</i>										
Ashmol.1923.69	41 IV	9035	-3.7	6.3	-8.0	0.9!	-7.3	10.5	-	-
VS 15 35	86 IV	9592	-6.8	1.2	-6.6	1.3			+	+
TU 16	97 VII	9731	-2.5	4.5	-2.3	5.6			+	+
A 3679	140 VII	10262	-6.6	0.9	-6.2	3.2	-17.3	8.2	+	+

Source	Date	Syz #	Δh_1	Δh_2	Δh_3	Δh_4	Δ	h	H	PD
BRM II 45	154 III	10432	-8.2	3.7	-0.2	11.6	-4.5	9.9	+	+
Thompson Cat.p.29	219 II	11235	-1.4	9.4	-8.6	0.9!	-8.8	10.3	-	-

A-2. Old Babylonian intercalary data

The following intercalations were contributed mostly by M. Stol and C.B.F.Walker, a few by H. Klengel, W. Moran and J. Weir. All texts with BM-numbers have been collated by Walker. W. W. Hallo gave us permission to quote a text to be published in YOS 15.

LFS contains a large number of intercalations, mostly communicated by Schnabel from unpublished Berlin texts, which cannot be verified now; it appears that these intercalations are very unreliable, and they were therefore enclosed in parentheses.

Sumuabum	14 years	
3 XII ₂		Kutscher, Bull. Wadsworth Atheneum, Spring/Fall 1971, p.43
Sumulael	36 years	
33 XII ₂		PRAK 1 B.262
Sabium	14 years	
Apilsin	18 years	
Sinmuballit	20 years	
1		
2		
3		
4		
5		
6		
7	itu.dirig.ga	VAS 8 26
8		
9	XII ₂	VAS 8 30
10		
11		
12	- itu dirig ga	(Stol 16-Sep 85)
13		
14		
15		
16		
17		
18		
19	itu.dirig.kam	TCL 1 72
20		

Hammurapi 43 years

1		
2		
3	itu.dirig.ga	VAS 8 96
4		
5		
6		
7		
8		
9		
10	(XII ₂	LFS unpubl.)
11		
12		
13	(VI ₂	CT 33 47a; probably Samsuiluna 8)
14		
15	itu.dirig.ga	VAS 8 131-132; (XII ₂ LFS unpubl.)
16	XII ₂	BE 6/2 70; cf. VAS 9 5:9
17		
18		
19		
20		
21		
22		
23	(XII ₂	LFS unpubl.)
24	itu.dirig	BAP 80
25	(XII ₂	LFS unpubl.; PSBA xxxiv 24)
26	XII ₂	BM 81151; BM 81680; BM 82129
27		
28		
29	itu.diri.ga	BM 22601: mu alam d ^a ša-la
30	(XII ₂	LFS unpubl.)
31		
32	XII ₂	CT 47 42 (coll. Walker)
33	XII ₂	BM 78795-6 (King LIH 3, p.13,1)
34	XII ₂	Tell Sifr 35a (itu.dirig, coll. D. Charpin); BM 17267 (? coll. Walker)
35	VI ₂	BM 81622
36	(VI ₂	LFS unpubl.: mu e-me-te-ur-sag)
37		
38	VI ₂	TLB 1 101
39	(VI ₂	LFS unpubl.: mu kur su.bir.ki)
40	VI ₂	RA 70 56; MAOG 13/3 23 nt.1; BM 82200
41		
42		
43	VI ₂	BM 22589

 Samsuiluna 38 years

1		
2	(XII ₂	LFS unpubl.)
3	VI ₂	YOS 12 72-73; CT 4 13a:2,8,15
4		
5	VI ₂	Tell Sifr 71; TCL 1 114 BM 22536; BM 79487
6		
7		
8	VI ₂	CT 33 47a; Tell Sifr 80; PBS 8/2 192; BM 79994 BM 80981
9	XII ₂	CT 47 62; (VI ₂ LFS unpubl.)
10	(VI ₂	LFS unpubl.)
11	ity dirig.ga	JCS 11 34, no.20 <i>cancel (Std. 16 Sep 85)</i>
12		
13		
14		
15		
16	(VI ₂	LFS unpubl.)
17	(VI ₂	LFS unpubl.)
18		
19		
20	XII ₂	BE 6/2 53; YOS 12 399-400; BM 81804
21		
22		
23	XII ₂	CT 8 32a; YOS 12 441; TLB 1 129
24		
25		
26		
27	XII ₂	BIN 7 205; Riftin 41; TLB 1 86; BM 80928; BRM 4 40; BM 22547
28	(XII ₂	LFS unpubl.)
29(?)	XII ₂	BM 81638, BM 22543 <i>all three</i> <i>(both have: mu gibil), BM 22544</i>
30		
31	XII ₂ (?)	CT 48 16
32		
33		
34		
35		
36		
37	(XII ₂	PSBA 34 24)
38		

Abieshuh 28 years

h	VI ₂	BE 6/1 66
i	VI ₂	BM 81512
m	I ₂ (!)	CT 8 27a
0	itu.dirig(!).ga	JCS 5 86 MAH 16506
q	XII ₂	CT 6 38a
u	VI ₂	JCS 2 80 no.9:3
28	regular	

Ammiditana 37 years

1	regular	(cf. BE 6/1 82:14-22. Between Ae 28 III 30
2	regular	and Ad 5 XII 30 there are 5 years and
3	regular	10 months.)
4	XII ₂	BE 6/1 91; YOS 13 205
5		
6		
7		
8		
9		
10	XII ₂	PBS 8/2 202; RA 73 70; BM 17313; BM 78465
11	(XII ₂	LFS unpubl.)
12		
13	XII ₂	BM 22522
14	XII ₂	YOS 13 1; HSM 48 (coll. Moran)
15		
16		
17		
18		
19		
20		
21		
22	XII ₂	YOS 13 197; PSBA 34 24; see YOS 13 p.1 and JCS 13 39a
23		
24		
25	XI ₂ (!?)	YOS 13 272
26	XII ₂	CT 6 39a=BM 80596; BM 16684(? coll. Walker)
27	XII ₂	BE 6/2 109
28	XII ₂	BM 80977
29		
30		
31		
32	XII ₂	BM 78668; BM 16535
33	XII ₂	BE 6/2 112
34		
35		
36		
37	XII ₂	Kraus, Edikt 28 3'; RA 63,48 37-39; YOS 15 72 , BM 78477

Ammisaduqa 21 years

1		
2		
3		
4	XII ₂	VAS 7 76; BM 17563
5	(VI ₂	Venus Tablet; LFS unpubl.)
6		
7		
8		
9		
10	VI ₂	YOS 13 532; BE 6/1 106; BM 81130
11	VI ₂	CT 8 3a; BM 81350
12		
13	XII ₂	YOS 13 404; TLB 1 211; BIN 7 208-9; BM 78461; BM 81396; BM 81747; Dalley, Edinb. no.20, 20 79435
14	(VI ₂	LFS unpubl., probably wrong)
15		
16		
17		
18		
19	(VI ₂	Venus Tablet)
20	(VI ₂ or XII ₂	Venus Tablet)
21		
17+a (=20?)	XII ₂	TCL 1 171; BAP 9; VAS NF II 99; YOS 13 53, BM 78461
17+b (=21??)		
17+c (=1)		
17+d (=19?)	VI ₂	YOS 13 146

Samsuditana 31 years

1		
2		
3		
4		
5		
6	I ₂	YOS 13 219
7		
8		
9		
10		
11		
12		
13	XII ₂	YOS 13 337
14		
15		
16(?)	VI ₂	VAS 22 68
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		
31		

A-3. Old Babylonian month-length data

Most of the 30-day months below were collected by G. van Driel and M. Stol. Some were contributed by C.B.F. Walker and by J. Weir, and a fair number was lifted from the catalogue of YOS 12. We thank W. W. Hallo for his permission to quote texts from the still unpublished YOS 15, as well as YBC texts belonging to the archive of Shep-Sin, that will be published by M. Stol. The signature AUAM refers to texts in the Andrews University Archaeological Museum; they are quoted on the basis of copies made by M. Sigrist and communicated by him to M. Stol. Again, all texts with BM-numbers have been collated by Walker.

The first set of tables gives the raw data. The second set gives the comparison with calculation of the month-lengths of Hammurapi 30 to Samsuiluna 11, of the last 14 years of Ammiditana, and of the first 16 years of Ammisaduqa. For each year, the number of the New Year syzygy and the corresponding solar/lunar longitude are given in square brackets. For the first year, also the Julian date of the New Year's day (month I day 1) is given. The meaning of Δh_1 , Δh_2 , Δh_3 and Δh_4 is as in Section 1 of the Appendix. Agreement/disagreement with calculation is indicated by +/- in column H; misses that might have been caused by marginal visibility conditions are indicated by an exclamation mark.

Through an oversight, three 30-day months, namely Hammurapi 30 X, 37 IV and 42 V, were omitted in the statistical calculations (two of them agree with the -1701 chronology, the third is a marginal miss).

Date		Source
Sumulael		
5 III	30	Gautier 58(?)
Hammurapi		
1 II	30	OECT 8 15 (case)
2 VI	30	BM 78526
4 I	30	CT 8 18b
II	30	AUAM 73.2754
7 XII	30	BE 6/1 25
26 V	30	TCL 1 87
30 X	30	VAS 13 20a
31 III	30	ARN 66 (or year 30?)
32 VIII	30	BA 5 13
XI	30	BA 5 12
33 XI	30	CT 45 26 , BM 23347
34 XII	30	VAS 9 57
37 IV	30	CT 48,65, BM 80251
38 III	30(?)	Arnaud Syria 53 p.72
IV	30	TCL 11 159
IX	30	UMBS 8/2 263
XI	30	Boyer HE 135
XII	30	TLB 102
39 VI	30	AUAM 73.2330
VII	30	YBC 4372
VIII	30	VAS 9 148-9
41 VI(?)	30	YBC 7778

Date		Source
XII	30	VAS 9 138; YBC 4288
42 V	30	BM 22685; BIN 77431
VII	30(?)	Jean, Sumer et Akkad 189
XII	30	VAS 9 109-110; UET 5 518
43 XI	30	BE 6/1 33; YBC 7787
Samsuiluna		
1 I	30	YOS 12 3
V	30	AUAM 73.1017 (year 1?)
VIII	30	Tell Sifr 60a
X	30	Arnaud Syria 53 p.73; YOS 15 86
XI	30	Frank 31
2 V	30	BM 16190
X	30	YOS 12 54; YOS 12 56
XII	30	YOS 12 58
3 II	30	YOS 12 64
IV	30	BM 82134
VII	30	Arnaud Syria 53 p.73
IX	30(?)	YOS 12 84
4 III	30	YOS 12 102
VI	30	Tell Sifr 66a
XI	30	Frank 36; AUAM 73.2141
5 III	30	HE 111 (RA 15 p.191)
VI	30	YOS 12 144
XII	30	YOS 12 162
6 V	30	AUAM 73.2665
VI	30	Boyer HE 131
VIII	30	Gordon 59(?); YOS 12 188
XII	30	UET 5 834; YOS 12 207,209,210
7 IV	30	BIN 2 75
VIII	30	Gordon 57; YOS 12 244
IX	30	Tell Sifr 79; YOS 12 250
XI	30	AUAM 73.2206
XII	30	Riftin 86; AUAM 73.2609
8 II	30	YOS 12 287-88
VI	30	Riftin 91; YOS 12 308
VI ₂	30(?)	BM 80981
VIII	30	YOS 12 311
9 XI	30	BA 5 12
10 XI	30	YOS 12 324-25
XII	30	YOS 12 328-330
11 IV	30	UMBS 8/2 150
V	30	YOS 12 346
XII	30	YOS 12 356; AUAM 73.2667
15 V	30	Biot, Geneve 24
18 VIII	30	A.5861 (Chicago)
X	30	Edzard, ed Der IM 52.240(b)
XII	30	Edzard, ed Der 203
19 VIII	30	TJAUB 15 FM 40
XII	30	YOS 12 394
21 XII	30	Biot, Geneve 25

Date		Source
22 X	30	ARN 165
XII	30	BM 16813,+a
23 XII	30	YOS 12 440
24 V	30	YOS 12 448
XII	30	YOS 12 458
25 VII	30	BM 82112
XII	30	CT 47 65
26 XII	30	TJB pl.XV(MAH 16139)
27 I	30	YOS 12 485
XII	30	TJB pl.L(MAH 16429); YOS 12 500
28 I	30	Birot Geneve 29(?); YOS 12 508
V	30	TJB pl.XXXV(MAH 16304)
IX	30	UMBS 8/1 191
XI	30	VAS 18 4
XII	30	TLB 1 91
30 VI	30	TLB 1 142
Abieshuh		
C IV	30	BM 80899
h XII	30	CT 47 69
i XII	30	BM 81221
m XII	30	TLB 1 228
n VIII	30	Crozer 152 (JCS 2 no.9)
o I	30	Kich II C 73
p XII	30	YOS 13 504
28 III	30	BE 6/1 82:14-22
V	30	BM 78592
VII	30	CT 48 93
Ammiditana		
1 X	30	VAS NF 2 15
XII	30	CT 6 26b; BM 81465
2 XI	30	Di 720 (K. van Lerberghe)
4 VIII	30	CT 33 47b
XII ₂	30	BE 6/1 91
5 XII	30	BE 6/1 82
6 IV	30	CT 45 46, BM 80161
7 XII	30	UET 5 518; YOS 13 126
14 III	30	CT 45 48
XII ₂	30	YOS 13 1; HSM 48
24 I or V	30	BM 81569
24 VII	30	TCL 1 153
26 VI	30	VAT 5912 (Kugler, SSB II p.246)
IX	30	VAT 5806 (Kugler, SSB II p.246)
27 XII ₂	30	BE 6/2 109
29(?) II	30	YOS 13 254
30 IV	30	TJAUB pl.39(H 31)
31 II	30	BE 6/1 83
XII	30	BE 6/1 84
32 XII	30	BM 78609
34 VIII	30	YOS 13 79
IX	30	VAS 7 60

Date		Source	
36 II	30	YOS 13 57	
XII	30	BM 78719	
Ammi saduqa			
1 VII	30	TJDB p.31 (MAH 16218)	
VIII	30	VAS 7 68	
XII	30	BM 78640	
3 VI	30	VAS 7 73	3 IV 30 BM 80926
4 XII ₂	30	VAS 7 76	4 X 30 BM 80926
5 XII	30	YOS 13 165	
6 VI	30	BM 80804	
7 XII	30	YOS 13 126	
11 II	30	BM 80984	
12 IV	30	Edzard, ed Der no.49	
VIII	30	BM 81105	
13 II	30	BM 17146	
XII	30	YOS 13 220	
14 VI	30	Frank 28	14 IV 30 BM 81257
VIII	30	JCS 11 p.93	
15 II	30	YOS 13 221	
X	30	RA 69 p.188 (BM 13596)	
XII	30	CT 2 18	
16 I	30	Meissner 107; VAS 7 109:3	
XI	30	UMBS 14 pl.64 no.1078;	
		VAT 5925,5938 (Kugler, SSB II p.246)	
XII	30	VAS 7 121	
17+a XI	30	VAS 7 133	17+c XII 30 BM 81257
XII	30	VAS 7 139; CT 48 76	
17+b V	30	CT 48 78	
17+d III	30	BM 81079	
X	30(?)	YOS 13 65	
13 or 17+a XII ₂	30	BM 81096	
Samsuditana			
2 XII	30	YOS 13 262	
3 XI	30	BM 81146	
7 I	30	YOS 13 538	
11 VI	30	BM 78378	
16 I	30	PBSA 39(1917) pl.xii (p.96)	
26 or 27 VI	30	VAS 22 77	

Comparison with calculation				
Date		Syz #	L	H
Hammurapi				
30		[-10116	318° -1818 Feb 23]	
	X	-10107		+
31		[-10104	308°]	
	III	-10102		+
32A		[-10092	298°]	
	VIII	-10085		+
	XI	-10082		- ($\Delta h = -1.0$)
33A		[-10079	316°]	
	XI	-10069		-
34A		[-10066	334°]	
	XII	-10055		+
35U		[-10053	352°]	
36		[-10040	10°]	
37		[-10028	359°]	
	IV	-10025		-! ($\Delta h = -0.7$)
38U		[-10016	349°]	
	III	-10014		+
	IV	-10013		-! ($\Delta h = 0.9$)
	IX	-10007		+
	XI	-10005		-
	XII	-10004		+
39		[-10003	6°]	
	VI	-9998		+
	VII	-9997		+
	VIII	-9996		-
40U		[-9991	356°]	
41		[-9978	14°]	
	VI	-9973		+
	XII	-9967		+
42		[-9966	4°]	
	V	-9962		+
	VII	-9960		+
	XII	-9955		- ($\Delta h = 1.0$)
43		[-9954	354°]	
	XI	-9944		-! ($\Delta h = 0.9$)
Samsuiluna				
1		[-9942	343° -1804 Mar 20]	
	I	-9942		-
	V(?)	-9938		-
	VIII	-9935		+
	X	-9933		+
	XI	-9932		-! ($\Delta h = 0.3$)
2		[-9930	332°]	
	V	-9926		+
	X	-9921		+
	XII	-9919		+
3U		[-9918	322°]	

Date	Comparison with calculation		
	Syz #	L	H
4	II	-9917	+
	IV	-9915	+
	VII	-9911	+
	IX	-9909	-
	[-9905	340°]	
5U	III	-9903	+
	VI	-9900	+
	XI	-9895	+
	[-9893	329°]	
	III	-9891	+
6	VI	-9888	-! ($\Delta h = -0.9$)
	XII	-9881	-
	[-9880	347°]	
	V	-9876	-! ($\Delta h = -0.0$)
	VI	-9875	+
7	VIII	-9873	+
	XII	-9869	+
	[-9868	337°]	
	IV	-9865	+
	VIII	-9861	+
8U	IX	-9860	+
	XI	-9858	-
	XII	-9857	+
	[-9856	327°]	
	II	-9855	-
9A	VI	-9851	+
	VIII	-9848	+
	[-9843	345°]	
10	XI	-9833	-! ($\Delta h = 0.5$)
	[-9830	3°]	
	XI	-9820	-! ($\Delta h = -0.4$)
11A(?)	XII	-9819	+
	[-9818	352°]	
	IV	-9815	-
12	V	-9814	+
	XII	-9807	+
	[-9805	10°]	

Date	Comparison with calculation						
	Syz #	L	Δh_1	Δh_2	Δh_3	Δh_4	H
Ammiditana							
22A		[-8866 342°	-1717 Mar 19]				
23		[-8853 0°]					
24		[-8841 350°]					
	VII	-8835	-4.4	6.6	-1.0	11.1	+
25		[-8829 339°]					
26A		[-8817 328°]					
	VI	-8812	-0.3!	10.7	-7.2	2.8	-!
	IX	-8809	-8.4	3.7	-0.1	13.9	+
27A		[-8804 346°]					
	XII ₂	-8792	-10.9	2.0	-3.5	8.5	+
28A		[-8791 4°]					
29		[-8778 22°]					
	II	-8777	-7.8	4.1	-3.4	7.4	+
30		[-8766 12°]					
	IV	-8763	-3.3	8.4	-0.6	10.6	+
31		[-8754 2°]					
	II	-8753	-12.2	1.7	-3.1	10.7	+
	XII	-8743	-7.9	3.2	-2.6	10.0	+
32A		[-8742 351°]					
	XII	-8731	-9.1	1.0	-6.4	4.9	+
33A		[-8729 9°]					
34		[-8716 27°]					
	VIII	-8709	-7.7	1.1	-4.8	5.5	+
	IX	-8708			-1.1	10.0	+
35		[-8704 16°]					
36A(?)		[-8692 5°]					
	II	-8691	-6.9	4.3	-3.0	7.7	+
	XII	-8681	-12.7	1.0	-3.9	9.1	+
37A		[-8679 23°]					
Ammi saduqa							
1		[-8666 41°	-1701 May 19]				
	VII	-8660	-7.0	0.3	-6.0	3.8	+
	VIII	-8659			-0.7	12.3	+
	XII	-8655	-12.5	1.9	-2.1	11.9	+
2		[-8654 31°]					
3		[-8642 21°]					
	VI	-8637	-0.9	7.8	-1.0	8.1	+
4A		[-8630 11°]					
	XII ₂	-8618	-11.0	0.5	-4.6	7.4	+
5U		[-8617 28°]					
	XII	-8605	-7.0	3.9	-1.5	9.6	+
6		[-8604 46°]					
	VI	-8599	-0.2!	13.3	-5.0	7.7	-!
7		[-8592 35°]					
	XII	-8581	-9.2	2.6	-3.4	7.4	+
8		[-8580 25°]					
9		[-8568 14°]					

10U		[-8556	4°]					
11U		[-8543	22°]					
	II	-8542		-6.5	6.9	-11.7	0.1!	-!
12		[-8530	40°]					
	IV	-8527		-7.3	4.3	-2.4	8.9	+
	VIII	-8523		-7.8	0.4	-5.8	3.3	+
13A		[-8518	30°]					
	II	-8517		-3.7	9.9	-9.1	4.1	-
	XII	-8507		-9.4	1.7	-4.7	7.3	+
14		[-8505	48°]					
	VI	-8500		-8.0	1.7	-2.3	7.6	+
	VIII	-8498		-7.0	2.1	-4.7	5.4	+
15		[-8493	37°]					
	II	-8492		-9.0	2.4	-3.9	8.2	+
	X	-8484		-4.5	7.0	-11.4	0.1!	-!
	XII	-8482		-6.6	4.6	-2.6	8.3	+
16		[-8481	26°]					
	I	-8481				-10.8	0.8!	-!
	XI	-8471		-4.0	8.8	-9.5	2.9	-
	XII	-8470				-3.3	8.3	+
17		[-8469	16°]					
18		[-8457	6°]					
19U		[-8445	355°]					
20A		[-8432	13°]					
21		[-8419	31°]					

A-4. Larsa data

The following intercalations and 30-day months were collected by M. Stol and G. van Driel. The years 28ff. are problematical, see F. R. Kraus, ZA 53 (1959) 136-167.

Intercalary years			
Waradsin	13 years		
1			
2			
3			
4	XII ₂	UET 5 733	
5	XII ₂	YOS 5 7	
6			
7	XII ₂	YOS 5 82	
8			
9			
10	XII ₂	TLB 1 3; YOS 5 119	
11			
12			
13			
Rimsin	60 years		
1			
2	XII ₂	UET 5 303,332,360,809; TCL 10 18	
3			
4	XII ₂	UET 5 814	
5			
6			
7	XII ₂	YOS 5 176,210,212; YOS 8 69	
8			
9			
10			
11			
12	XII ₂	UET 5 604	
13			
14	XII ₂	UET 5 307	
15			
16	XII ₂	TCL 10 43; VAS 13 59	
17			
18	XII ₂	YOS 5 252; UET 5 326; Riftin 112:1-2; Figulla CBTBM I, BM 13945	
19			
20			
21			
22			
23			
24			
25			
26			
27			
28	XII.ki.3	UET 5 401	
29			

Intercalary years		
30		
31	VI ₂	YOS 8 92,106; VAS 13 67(itu.dirig)
	XII ₂	YOS 8 103
32	XII ₂	YOS 8 123
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49	XII ₂	PSBA 34 pl.X no.VII
50		
51		
52		
53		
54		
55		
56		
57		
58		
59		
60		

30-day months		
Waradsin		
7 III	30	AJSL 33, RFH 21
11 X	30	UET 5 330
Rimsin		
1 XI	30	UET 5 324
2 V	30	TCL 10 20
XI	30	UET 5 141
4 VI	30	UET 5 334
X	30	UET 5 772,773
5 III	30	UET 5 775
V	30	UET 5 335
XI	30	UET 5 336
6 IV	30	YOS 5 171
9 I	30	UET 5 197
10 II	30	YOS 5 194
XII	30	YOS 5 192; UET 5 554
16 I	30	UET 5 647
V	30	UET 5 652,653
VI	30	UET 5 656
17 VIII	30	Riftin 56
XI	30	Tell Sifr 15
18 XII ₂	30	UET 5 326
19 III	30	UET 5 158
XII	30	UET 5 98
21 X	30	UET 5 343
22 I	30	UET 5 237
X	30	UET 5 416; TCL 10 58
23 IV	30	TCL 10 60
VI	30	UET 5 234
X	30	UET 5 344,345
26 VII	30	UET 5 432
27 XII	30	TCL 10 70a,b
28ff.	omitted	

20. IX 3. 341 NYS 100-1000

		Comparison with calculation		
Date		Syz #	L	H
Rimsin				
1		[-10807	5° -1874 Apr 13]	
	XI	-10797		+
2A		[-10795	355°]	
	V	-10791		+
	XI	-10785		+
3		[-10782	12°]	
4A		[-10770	2°]	
	VI	-10765		+
	X	-10761		+
5		[-10757	19°]	
	III	-10755		-! ($\Delta h = 0.6$)
	V	-10753		+
	XI	-10747		- ($\Delta h = -1.0$)
6		[-10745	9°]	
	IV	-10742		+
7A		[-10733	359°]	
8		[-10720	17°]	
9		[-10708	7°]	
	I	-10708		+
10		[-10696	356°]	
	II	-10695		+
	XII	-10685		+
11		[-10684	346°]	
12A		[-10672	335°]	
13		[-10659	353°]	
14A		[-10647	342°]	
15		[-10634	0°]	
16A		[-10622	350°]	
	I	-10622		-
	V	-10618		-! ($\Delta h = -0.4$)
	VI	-10617		+
17		[-10609	8°]	
	VIII	-10602		+
	XI	-10599		+
18A		[-10597	358°]	
	XII ₂	-10585		-
19		[-10584	10°]	
	III	-10582		+
	XII	-10573		-! ($\Delta h = 0.6$)
20		[-10572	5°]	
21A?		[-10560	354°]	
	X	-10551		+
22		[-10547?	12°]	
	I	-10547		+
	X	-10538		+
23		[-10535	2°]	
	IV	-10532		+
	VI	-10530		+

Date	Comparison with calculation		
	Syz #	L	H
	X	-10526	+
24A?		[-10523 352°]	
25		[-10510? 10°]	
26		[-10498 0°]	
	VII	-10492	+
27		[-10486 349°]	
	XII	-10475	+

A-5. Ur III data

The following intercalary and month-length data were collected by R. Whiting. The alignment of the Umma calendar with the Drehem calendar is conjectural, especially after Shu-Sin year 7. We use the abbreviations Sh=Shulgi, AS=Amar-Sin, SS=Shu-Sin, IS=Ibbi-Sin; intercalary years are starred. Marginal visibilities ($|\Delta h| < 1$) are indicated in the column of the calculated month-lengths by + or - signs (lengthening or shortening of the month-length). Multiply attested month-lengths are indicated by 30*2, 30*3 etc. Agreements/disagreements are indicated by +/- signs; disagreements that might have been caused by marginal visibility conditions are marked by an exclamation mark.

Syz #	L	calc.	Drehem		Umma
Julian Date		length			
		30			
		29+			
		30-			
-13627	4°	30	Sh 40	1 29?	-
[-2102 Apr 13]		29+		2	
		30-		3	
		30		4	30
		30		5	30 +
		29		6	
		29		7	
		30		8	30 +
		29		9	
		29		10	29? +
		30		11	
		29		12	
-13615	353°	30	Sh 41*	1 30 ✓	+
[-2101 Apr 2]		29+		2	
		30-		3	
		30		4	
		30		5	
		30		6	
		29		7	
		29		8	
		30-		9	30
		29+		10	
		29		11	
		30		12	
		29		13	
-13602	11°	30	Sh 42	1	
[-2100 Apr 20]		29		2	30
		30		3	
		30		4	
		30		5	

Syz #	L	calc.	Drehem	Umma
Julian Date		length		
		29+	6	
		30-	7	
		29	8	3e
		30-	9	30? ✓ +
		29+	10	
		29	11	
		30	12	
-13590	1°	29	Sh 43 1	
[-2099 Apr 10]		29+	2	
		30-	3	
		30	4	
		30	5	
		30-	6	
		29+	7	
		30-	8	
		29+	9	
		30-	10	3e
		29+	11	
		29	12	3e
-13578	351°	30	Sh 44* 1	
[-2098 Mar 30]		29	2	
		29+	3	
		30-	4	29? 3e -!
		30	5	
		29+	6	
		30-	7	30 +
		30	8	
		29	9	
		30	10	
		30	11	3e
		29	12	3e
		29	13	
-13565	9°	30	Sh 45 1	
[-2097 Apr 18]		29	2	
		29+	3	
		30-	4	
		29+	5	
		30-	6	29? 3e -!
		30-	7	
		29+	8	3e
		30	9	30*2 ✓ +
		30	10	
		30-	11	
		29+	12	
-13553	358°	29	Sh 46 1	
[-2096 Apr 7]		30	2	30 +
		29	3	30 ✓ -
		29+	4	30*2 ✓ -!

Syz #	L	calc.	Drehem	Umma
Julian Date		length		
		30-	5	
		29	6 30? ✓ -	
		30	7	
		29+	8 30 ✓ -!	
		30-	9	
		30	10 30*3 ✓ +	
		30	11 30*2 ✓ +	
		29	12 30 ✓ -	
-13541 348°		30	Sh 47* 1	
[-2095 Mar 27]		29	2	
		30	3	
		29	4	
		29	5 30	
		30	6	
		29	7 30*3 ✓ -	
		30	8	
		29+	9	
		30-	10 30 +	
		30	11 30*2 ✓ +	
		29	12	
		30	13 29? -	
-13528 6°		30	Sh 48 1	
[-2094 Apr 15]		29	2	
		30	3	
		29	4	
		29	5	
		30	6	
		29	7	
		30	8 30? +	
		29+	9	
		30-	10	
		29	11 30 -	
		30	12	
-13516 355°		30	AS 1 1 30*2 ✓ +	AS 1 1
[-2093 Apr 4]		29	2 29? +	2 30 -
		30	3 30 +	3
		29+	4 30 -	4
		30-	5	5
		29+	6 30 ✓ -!	6
		30-	7 30 ✓ +	7
		30-	8	8
		29+	9	9
		29+	10 30 ✓ -!	10
		30-	11	11
		29	12	12
-13504 344°		30	AS 2 1 30 +	AS 2* 1
[-2092 Mar 23]		29	2	2
		30	3 30*2 ✓ +	3

Shulgit: 1/2 xi S 48

Syz #	L	calc.	Drehem	Umma
Julian Date		length		
		30-	4	4
		29+	5 30*2 ✓ -!	5
		30	6	6
		30	7	7
		29	8	8
		30	9	9
		29	10	10
		29	11 30*3 ✓ -	11
		30	12 30	12
-13492 334°		29	AS 3* 1	13
[-2091 Mar 13]		29+	2 30	AS 3 1 29 +
		30-	3 30 ✓ +	2
		30-	4 30 ✓ +	3
		29+	5	4 30 -!
		30	6 30*2 ✓ +	5
		30	7	6
		30	8	7
		30-	9 30*2 ✓ +	8
		29+	10 30 ✓ -!	9
		29	11 30	10
		29	12	11 30 -
		30	13 30 +	12
-13479 352°		29	AS 4* 1 30 -	AS 4* 1
[-2090 Apr 1]		29	2 30 -	2
		30	3 30 +	3
		29	4	4
		30	5 30 ✓ +	5
		30	6 30*2 +	6
		30	7	7
		30	8 30*3 ✓ +	8
		30-	9	9
		29+	10 30	10
		29	11 30 -	11
		29	12 29? +	12
		30	13	13
-13466 10°		29	AS 5 1 30*2 ✓ -	AS 5 1
[-2089 Apr 20]		29	2 30*2 -	2
		29+	3	3
		30-	4 30*2 ✓ +	4 30 +
		30	5 30*2 ✓ +	5
		30	6 30 ✓ +	6
		30	7	7 30 +
		30	8	8 30 +
		29	9 30 ✓ -	9 29 +
		30	10 30? +	10 30 +
		29	11	11 29 +
		29	12	12
-13454 0°		30	AS 6 1	AS 6* 1 30 +

Syz # L	calc.	Drehem		Umma		
Julian Date	length					
[-2088 Apr 8]	29	2	30	2		
	29	3		3	29	+
	30-	4	30	4		
	29+	5		5		
	30	6		6		
	30	7		7	30	+
	30	8	30? ✓ +	8	29(30)	
	29	9	30? ✓ -	9		
	30	10		10		
	29	11		11		
	30	12		12	30	+
-13442 350° [-2087 Mar 29]	29	AS 7 1		13		
	30-	2	30*2 ✓ +	AS 7 1		
	29+	3		2		
	29	4	30 ✓ -	3		
	30	5	30*2 ✓ +	4		
	30	6		5	29	-
	29	7	30	6	30	-
	30	8	30*2 ✓ +	7		
	29+	9	30*3 -!	8	29	+
	30-	10		9		
	29+	11		10		
	30-	12	30 ✓ +	11	29	-!
-13430 339° [-2086 Mar 18]	30	AS 8 1		12		
	29	2	30 ✓ -	AS 8 1		
	29+	3		2		
	30-	4	30 +	3		
	30-	5	30	4		
	29+	6	30 -!	5		
	30	7	30	6		
	29	8	30	7	30	-
	30	9	30*3 ✓ +	8		
	29	10	30	9		
	30-	11	30 ✓ +	10	30	+
	29+	12	30*2 ✓ -!	11		
-13418 328° [-2085 Mar 7]	30	AS 9* 1		12		
	29	2		AS 9 1		
	30	3		2		
	29+	4		3		
	30-	5		4		
	30	6	30 ✓ +	5		
	29	7		6		
	30	8		7		
	29	9		8		
	29	10		9		
	30	11	30? +	10		
	29	12		11		
	30	13	30	12		

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(ver 97) AS 9

Syz # L	calc.	Drehem	Umma
Julian Date	length		
-13405 346°	29	SS 1* 1	SS 1* 1
[-2084 Mar 25]	30	2 30*2 ✓ +	2
	30	3 30 +	3
	30-	4 30	4 30 ✓ +
	29+	5	5
	30	6 30 +	6
	29+	7	7
	30-	8	8
	29	9 30 -	9
	29	10	10
	30	11	11
	29	12 29? +	12
	30-	13	13 30 +
-13392 4°	29+	SS 2* 1	SS 2 1
[-2083 Apr 13]	30	2	2 29 -
	30	3 30 ✓ +	3
	30	4 30 ✓ +	4 30 +
	29+	5	5 29 +
	30-	6 30 ✓ +	6 30 ✓ +
	29	7	7 30 -
	30	8 30 ✓ +	8 30 +
	29	9	9
	29	10	10
	30-	11	11
	29+	12	12 29 +
	29	13	SS 3* 1
-13379 21°	30	SS 3 1	2
[-2082 May 1]	30	2	3
	30-	3 30*2 ✓ +	4 30 +
	29+	4	5
	30-	5	6
	30	6 30 +	7
	29	7	8
	30-	8	9 29 -!
	29+	9	10 30 -!
	29	10	11 29 +
	30	11	12 30 +
	29	12 29? +	13
-13367 11°	29	SS 4 1	SS 4 1 29 +
[-2081 Apr 21]	30	2	2
	30-	3 30 ✓ +	3 30 +
	29+	4	4
	30	5	5
	30	6	6 30 +
	29+	7	7 30 -!
	30-	8 30*2 +	8 30 +
	29+	9	9 30(29)
	30-	10	10 30 ✓ +

Syz #	L	calc.	Drehem			Umma		
Julian Date		length						
-13355 1° [-2080 Apr 10]		29	11			11	29	+
		30	12	30 ✓	+	12	30	+
		29	SS 5* 1			SS 5 1	29	+
		29	2			2		
		30	3			3	29	-
		29+	4			4		
		30-	5	30?	+	5		
		30	6			6		
		29	7			7		
		30	8			8		
		30	9			9		
		29	10			10		
		30	11	30	+	11		
		29	12			12		
		30	13			SS 6* 1		
-13342 19° [-2079 Apr 29]		29	SS 6* 1			2		
		29	2			3	29	+
		30	3	29?	-	4		
		29	4	30	-	5		
		30	5			6		
		29	6			7	29	+
		30	7			8		
		30	8			9		
		29+	9			10		
		30-	10	29?	-!	11		
		30	11	30	+	12		
		29	12			13		
		30	13	30*2	+	SS 7 1		
		29	SS 7 1			2		
		29+	2			2		
-13329 37° [-2078 May 18]		30-	3			4		
		29	4			5		
		30-	5			6		
		29+	6			7		
		30	7			8		
		30-	8			9		
		29+	9			10		
		30	10			11		
		30	11			12		
		29	12			13?		
		30	SS 8 1			SS 8 1		
		29	2			2		
		29+	3			3		
		30-	4			4		
		29	5			5		
-13317 27° [-2077 May 7]		30-	6			6		
		29+	7	29	+	7		
		30	8	30	+	8		

Syz #	L	calc.	Drehem			Umma		
Julian Date		length						
-13305 16° [-2076 Apr 25]		29	9	29	+	9	29	+
		30	10	30*2	+	10		
		30	11	30	+	11		
		29	12	30	-	12		
		30	SS 9	1		SS 9	1	
		29+	2			2		
		30-	3			3		
		29	4	30	-	4		
		30	5			5	30	+
		29	6			6		
		30	7	30*2	+	7		
		29	8			8	30	-
		30	9			9		
		29	10	30*3	-	10		
		30	11	30	+	11		
		29	12			12	30	-
-13293 5° [-2075 Apr 14]		30	IS 1*	1	30? ✓	+	IS 1*	1
		30	2			2		
		29	3	30		3		
		30	4	30		4		
		29	5			5		
		30	6			6		
		29	7			7		
		30	8			8	30	+
		29	9			9		
		30	10			10		
		29	11	30		11		
		29+	12	30	-!	12		
		30	13			13		
		30	IS 2*	1		IS 2*	1	
		29	2			2		
		30	3	30	+	3	29	-
-13280 23° [-2074 May 3]		30-	4			4		
		29+	5			5	29	+
		30	6			6		
		30	7			7		
		29	8	30		8		
		29+	9			9	29	+
		30-	10			10	29	-!
		29	11	30?	-	11		
		29	12	30		12	29	+
		30	13			13		
		29	IS 3	1		IS 3	1	
		30	2			2		
		29+	3	30		3		
		30-	4			4	30	+
		30	5			5		
		30	6	30		6		
-13267 41° [-2073 May 22]		29	IS 3	1		IS 3	1	
		30	2			2		
		29+	3	30		3		
		30-	4			4	30	+
		30	5			5		
		30	6	30		6		

Salmon T
ix SS 9
(viii - ix)

Syz #	L	calc.	Drehem	Umma	
Julian Date		length			
		30	7	7 30	+
		29	8	8	
		29	9	9 29	+
		30	10	10 30	+
		29	11	11	
		29	12	12	

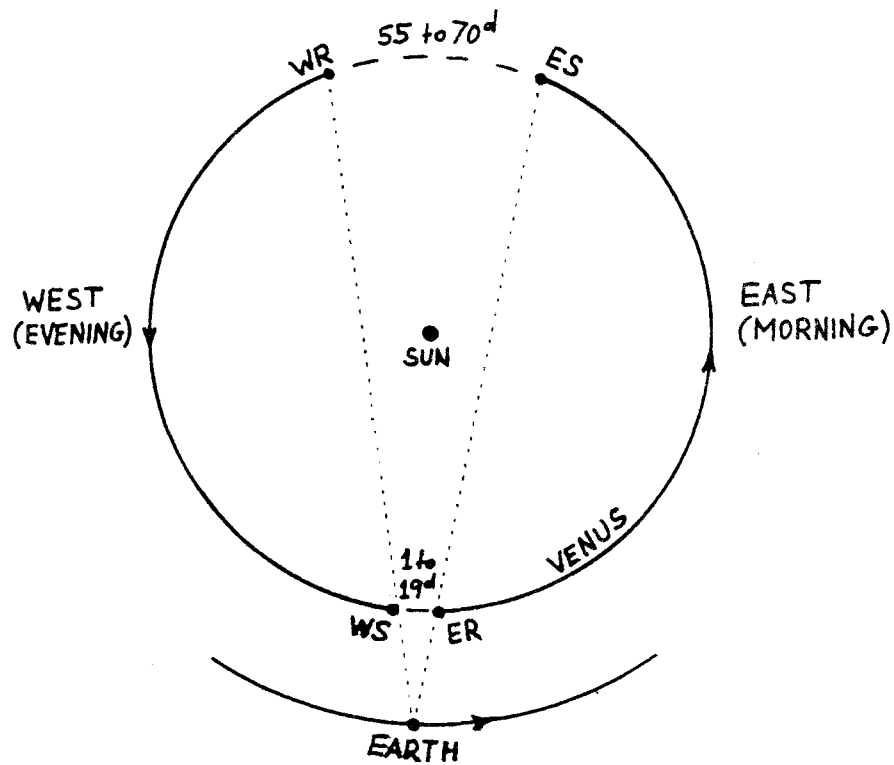


Figure 4.1.
Orbits of Venus and Earth, and the invisibility of Venus
near inferior and superior conjunction.

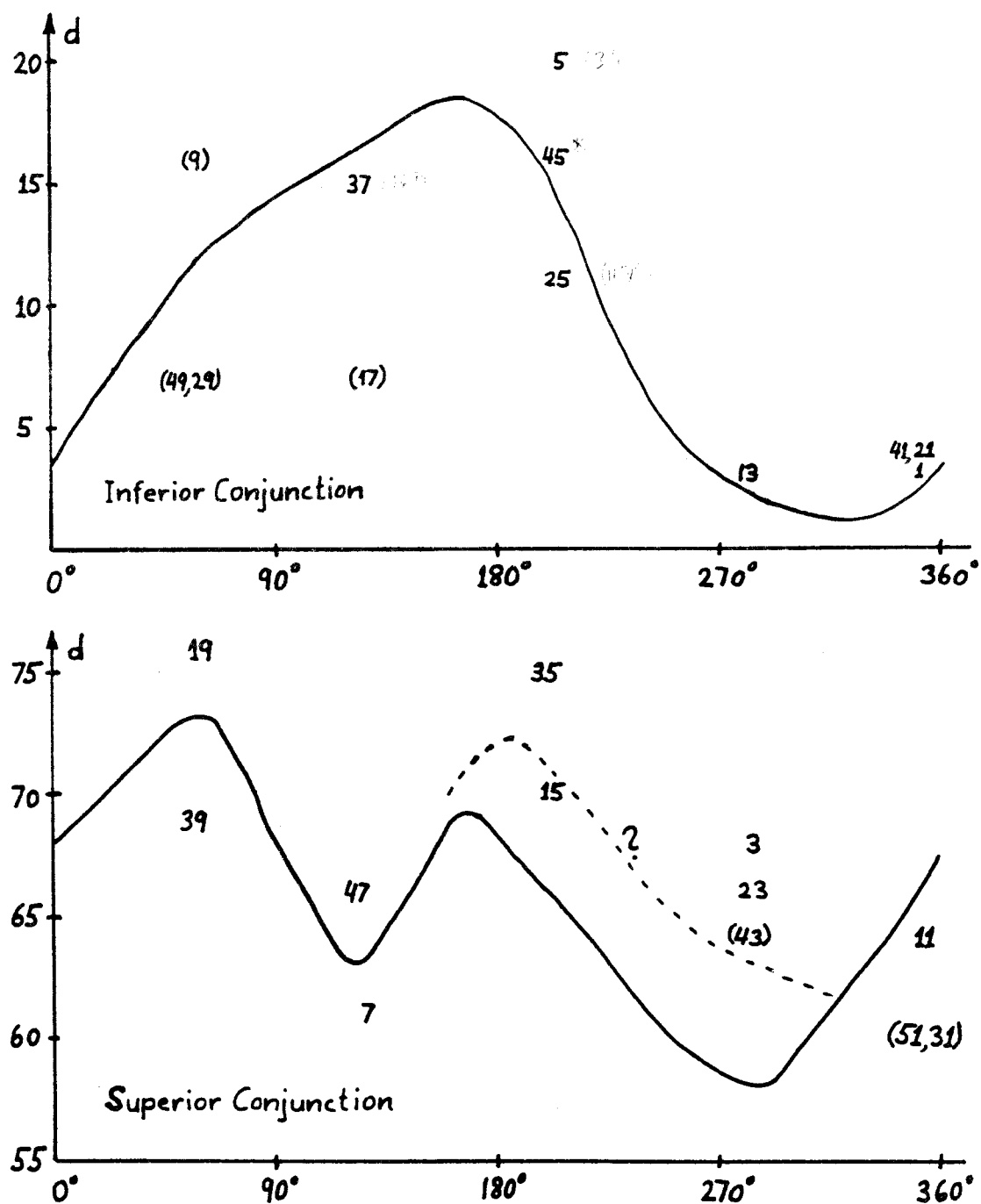


Figure 4.2.

Duration of invisibility of Venus, depending on the longitude at conjunction. The broken line indicates the conjectured increase of the *arcus visionis* between longitudes 150° and 270° . (The numbers identify lines in Table 4.2; they are positioned such that the abscissae correspond to the longitudes for the Long Chronology, while the ordinates correspond to the durations of invisibility as given in the Venus Tablet.)

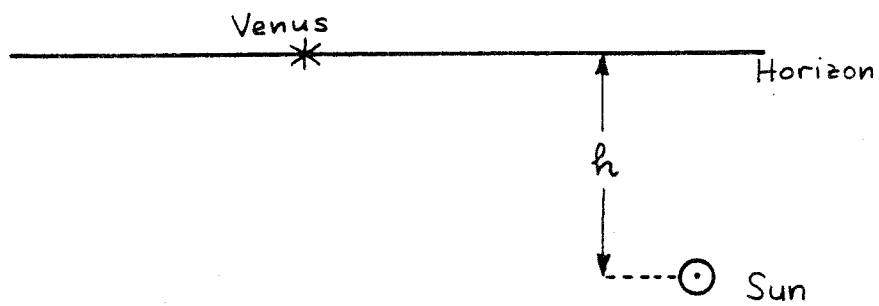


Figure 4.3.
The *arcus visionis* h of Venus.

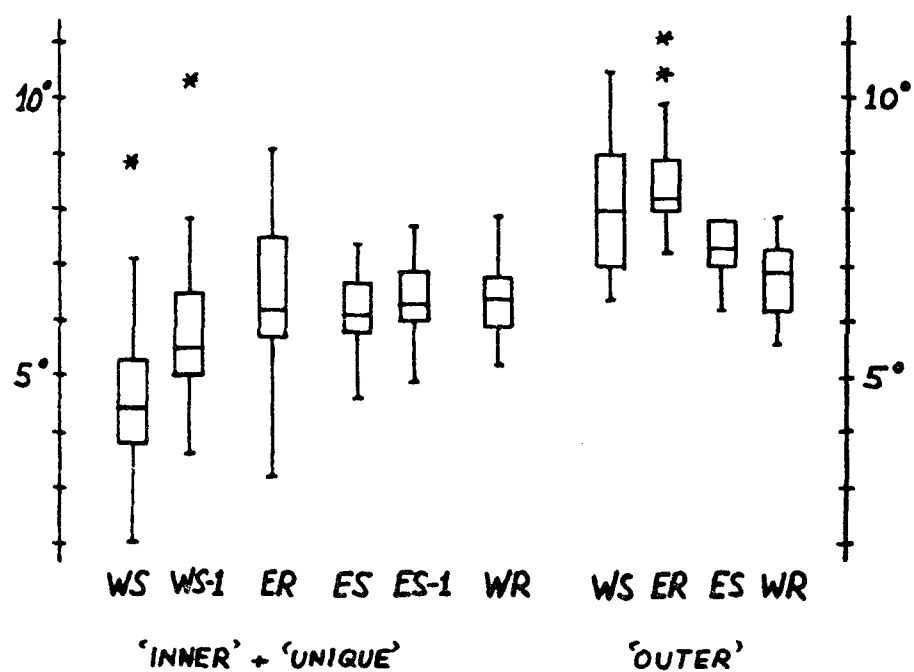


Figure 4.4.
Late Babylonian *arcus visionis* values for Venus.
One half of the observations fall within the boxes.
The whiskers extend to the extreme values
(putative outliers are marked by stars).

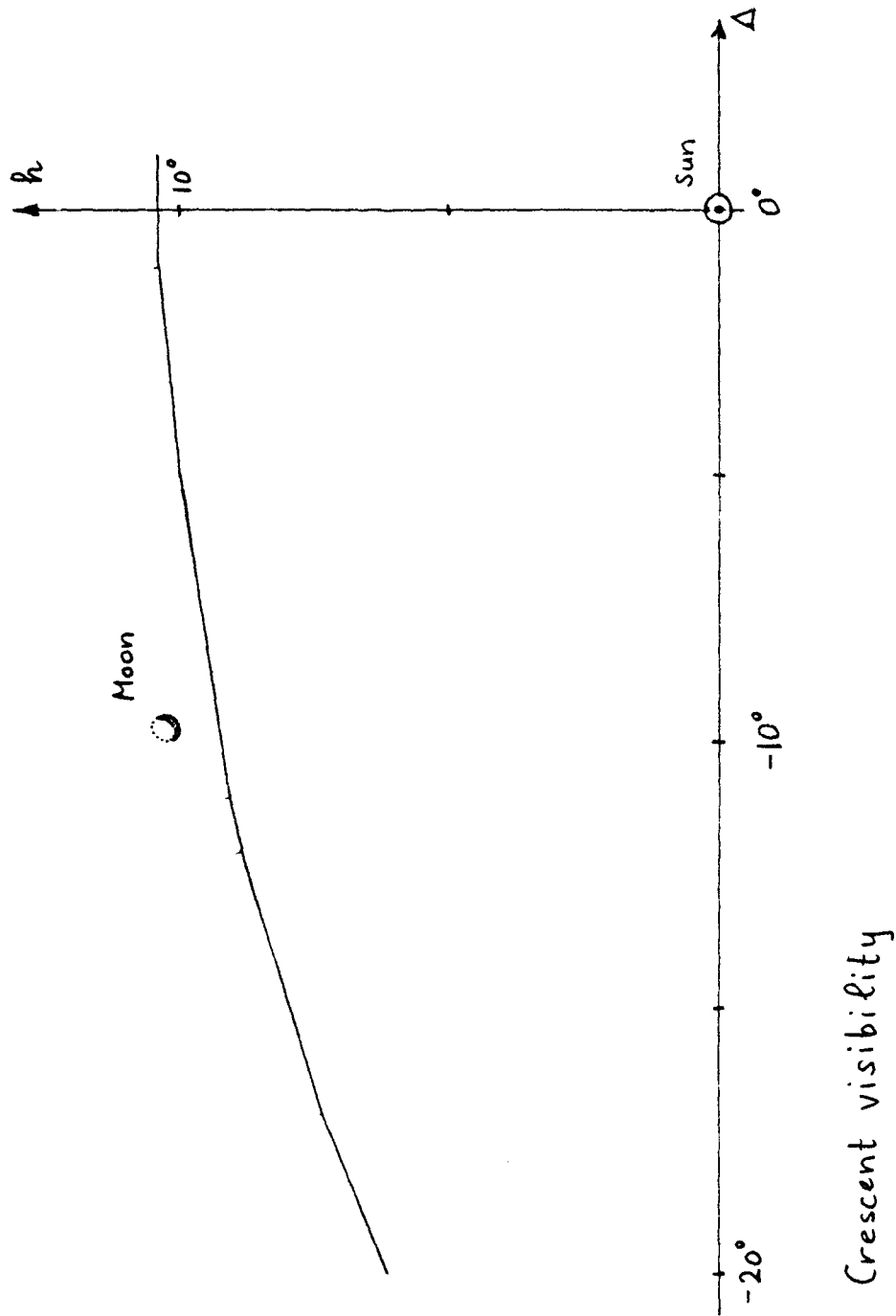


Figure 5.1.

Lunar crescent visibility. View of the western horizon at the time of sunset. The crescent is supposed to become visible after sunset if the moon is above the curve at the time of sunset.

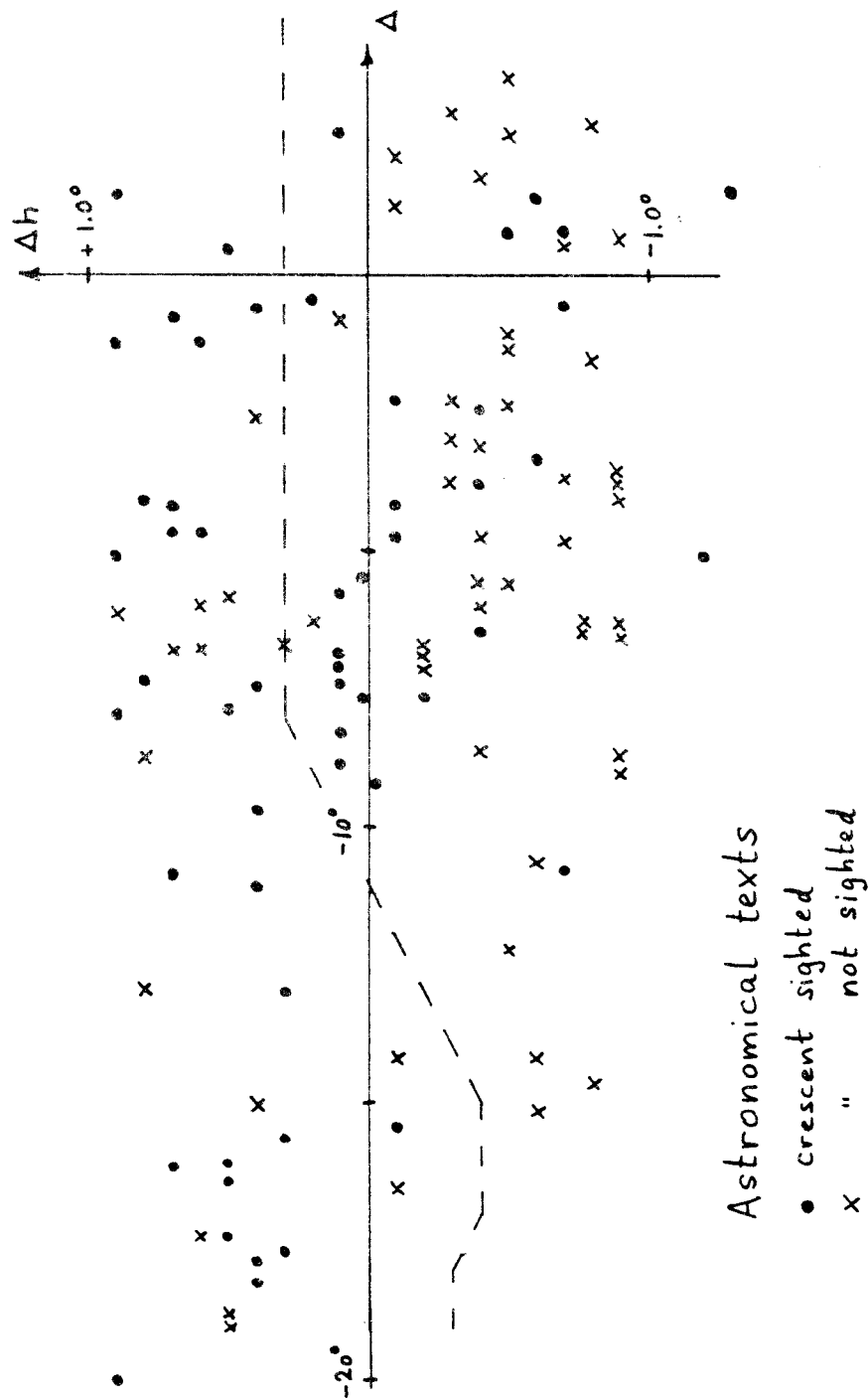


Figure 5.2.

Values of the PVN visibility criterion Δh plotted against the difference in azimuth Δ . According to PVN, the crescent is theoretically visible if Δh is positive, and according to LFS, if Δh is above the broken line (which plots the difference between the two columns of Table 5.1).

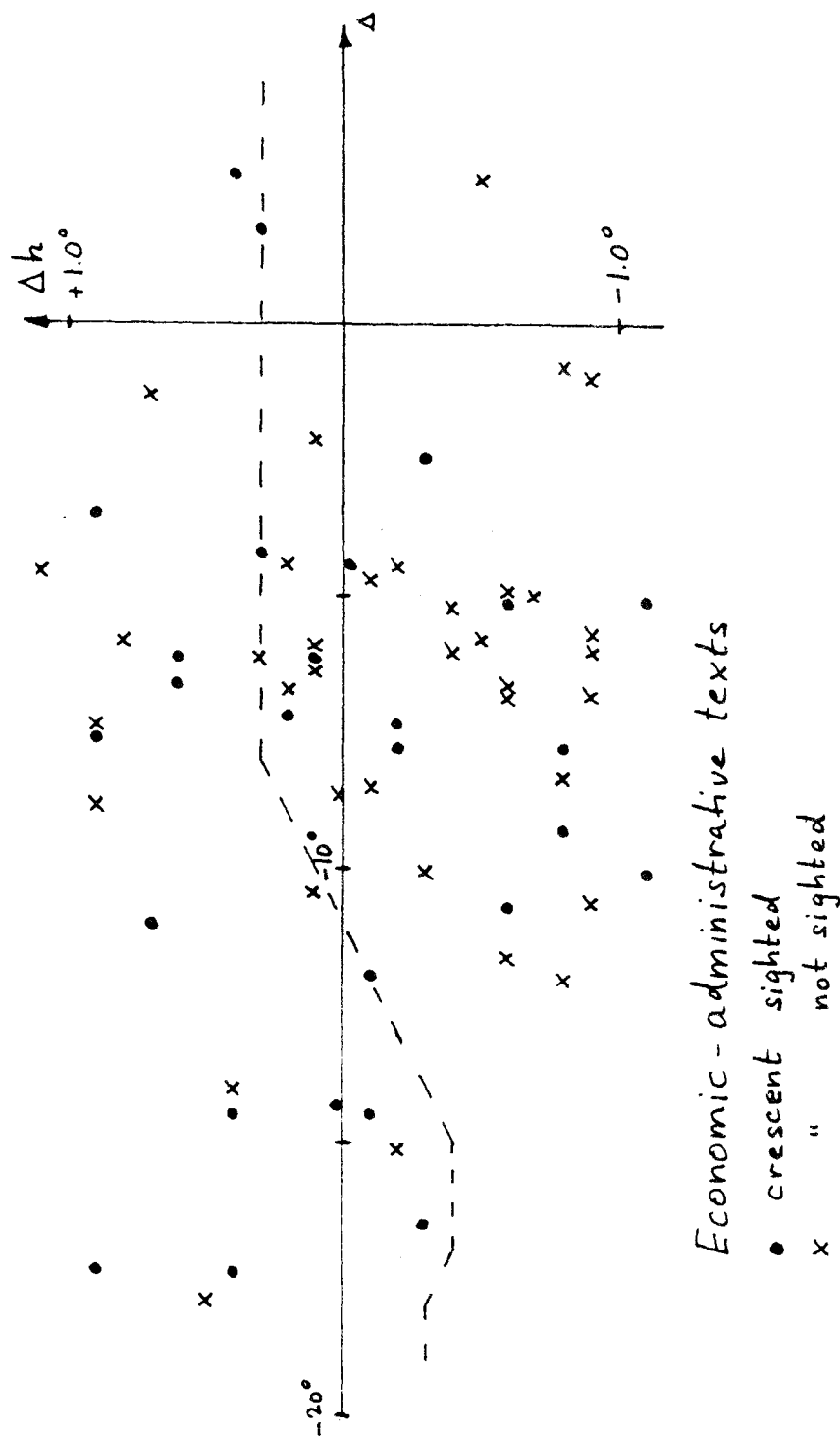


Figure 5.3.

Values of the PVN visibility criterion Δh plotted against the difference in azimuth Δ . According to PVN, the crescent is theoretically visible if Δh is positive, and according to LFS, if Δh is above the broken line (which plots the difference between the two columns of Table 5.1).

NEW MOONS AND CRESCENTS FOR BABYLON (YEARS -2456 TO +212)
 (Supplement to: Astronomical Dating of Babylon I and Ur III,
 by P.J.Huber et al.)

This tape contains 20 files.

FILE01 is this text,
 FILE02 to FILE12 contain the syzygy and crescent tables,
 FILE13 to FILE19 are FORTRAN programs,
 FILE20 is a test output.

The syzygy and crescent tables give:

- A. For the New Moon:
 - Number, date, time, longitude (as in Goldstine's tables).
- B. For the sunset on the last evening on which the crescent is invisible:
 - Time from sunset to moonset (upper limb, with parallax and refraction),
 - Difference in azimuth between moon and sun, when the latter is in the mathematical horizon,
 - Altitude of moon,
 - Visibility criterion (visible if positive).
 All four items are in degrees.
- C. For the sunset on the first evening on which the crescent is visible:
 - same four items as under B.
- D. For the following evening:
 - Time from sunset to moonset.
- E. For the sunset on the first evening on which the crescent is visible (i.e. the same evening as C.):
 - Julian day number,
 - date,
 - time of sunset (upper limb, with parallax and refraction),
 - number of the Babylonian day starting at this sunset (30, 1, or 2, according as the preceding month had 29, 30, or 31 days),
 - Babylonian king, year, month (day 1 of which begins on this evening), from Nabonassar on. Early intercalations are conjectural.

The calculations are made for Babylon (longitude 44.5, latitude 32.5), dates are in the Julian calendar, times are Babylon Mean Time (by definition: Universal, or Greenwich, Time plus 3 hours). They are based on the same elements as Tuckerman's and Goldstine's tables. Crescent visibility is determined according to Schoch's table E21 in P.V.Neugebauer's *Astronomische Chronologie* (1929).

For the Moon, only the five largest perturbations are included, and none for the Sun, except in the calculations for the time differences and for the time of sunset, where the full accuracy of the planetary program PLAPOS is used (more perturbation terms than in Tuckerman).

Each of the files FILE02 to FILE12 covers 3000 months (one per line), starting in the years -2456, -2213, -1971, -1728, -1486, -1243, -1000, -758, -515, -273 and -30 respectively.

The tables have been checked against a completely independent program of F.R. Stephenson (based on more modern theories), by comparing the results for 34 consecutive crescents in the years -748 to -746. The lunar positions show occasional discrepancies of 0.1 degrees. Stephenson's time differences between sunset and moonset agree exactly in 17 cases and are 0.1 time degrees (i.e. 24 seconds of time) larger in the other 17. The visibility criterion shows larger discrepancies (Stephenson uses the LFS table and extrapolates differently), namely up to 0.9 degrees.

The programs are provided for reference purposes. They were written for personal use, without much concern for efficiency and documentation; use them at your own risk. As they stand, they compile and run on a VAX-11/780 with the VMS operating system.

The program files contain:

FILE13	main program used to produce these tables,
FILE14 to FILE18	subroutines, in alphabetic order,
FILE19	a test program,
FILE20	output of the test program.

The central program of the subroutine collection is a general planetary positions subroutine (PLAPOS), with fairly extensive comments at the beginning.

Please inform me if you find errors in the programs (Address: Peter J. Huber, Department of Statistics, Harvard University, Cambridge MA 02138).

3120	-748APR12	9:43	14.33	4.3	1.7	4.3	-6.0	18.4	0.8	15.4	5.0	32.7	1447954	-748APR13	18:22	1	NBNSR	1U I
3121	-748MAY12	0:37	42.64	11.1	2.0	9.1	-1.2	25.6	-0.7	19.7	9.3	39.8	1447984	-748MAY13	18:41	1	NBNSR	1U II
3122	-748JUN10	15:32	70.83	4.0	3.7	3.7	-6.5	17.8	-1.4	13.4	3.1	30.4	1448013	-748JUN11	18:59	30	NBNSR	1U III
3123	-748JUL10	6:11	99.13	9.2	-0.6	7.4	-3.0	19.6	-8.7	15.6	6.2	28.6	1448043	-748JUL11	19: 8	1	NBNSR	1U IV
3124	-748AUG 8	20:24	127.76	9.8	-7.2	8.7	-1.0	17.5	-17.5	15.2	8.1	24.6	1448073	-748AUG10	18:57	1	NBNSR	1U V
3125	-748SEP 7	10: 1	156.86	2.0	-3.5	2.6	-7.6	9.2	-14.7	8.6	0.5	16.6	1448102	-748SEP 8	18:27	30	NBNSR	1U VI
3126	-748OCT 6	22:46	186.42	2.9	-10.5	3.3	-5.9	11.6	-22.4	9.7	4.6	21.5	1448132	-748OCT 8	17:49	1	NBNSR	1U VII
3127	-748NOV 5	10:32	216.35	8.4	-17.3	6.7	-0.6	21.8	-29.2	14.4	13.0	37.6	1448162	-748NOV 7	17:16	1	NBNSR	1U VIII
3128	-748DEC 4	21:27	246.42	5.8	-11.7	4.7	-4.3	23.0	-21.9	14.7	9.5	41.4	1448191	-748DEC 6	17: 1	30	NBNSR	1U IX
3129	-747JAN 3	7:50	276.38	2.2	-6.4	2.4	-7.4	21.1	-13.5	14.6	6.2	39.5	1448220	-747JAN 4	17:10	30	NBNSR	1U X
3130	-747FEB 1	18: 7	305.98	-2.9	-2.2	1.2	-11.5	15.2	-5.7	12.1	2.2	32.3	1448249	-747FEB 2	17:34	30	NBNSR	1U XI
3131	-747MAR 3	4:36	335.10	7.9	-0.5	7.2	-3.2	23.8	-1.8	20.0	9.7	39.3	1448279	-747MAR 4	17:58	1	NBNSR	2 I
3132	-747APR 1	15:36	3.75	1.0	2.5	1.7	-8.5	16.3	1.6	14.0	3.6	31.6	1448308	-747APR 2	18:16	30	NBNSR	2 II
3133	-747MAY 1	3:26	32.03	9.6	3.0	8.2	-2.0	17.3	-0.3	13.2	2.8	30.6	1448338	-747MAY 2	18:34	1	NBNSR	2 III
3134	-747JUN29	6:56	88.39	8.4	0.0	6.8	-3.6	19.3	-7.1	15.2	5.5	28.8	1448367	-747JUN30	19: 7	1	NBNSR	2 IV
3135	-747JUL28	22:47	116.93	8.4	-5.6	7.4	-2.4	16.2	-14.7	13.9	5.8	23.2	1448397	-747JUL30	19: 4	1	NBNSR	2 V
3136	-747AUG27	15:21	145.95	6.5	-11.2	6.3	-2.7	13.2	-21.3	11.9	6.3	19.9	1448427	-747AUG29	18:39	1	NBNSR	2 VI
3137	-747SEP26	7:33	175.48	6.3	-16.5	6.0	-1.5	14.1	-27.4	11.7	9.3	23.1	1448457	-747SEP28	18: 2	1	NBNSR	2 VII
3138	-747OCT25	22:29	205.41	1.1	-10.9	1.7	-7.4	11.2	-21.7	8.8	3.4	23.3	1448487	-747OCT27	17:27	30	NBNSR	2 VIII
3139	-747NOV24	11:47	235.55	9.8	-15.4	7.3	-0.6	25.8	-25.7	16.4	13.1	43.4	1448516	-747NOV26	17: 4	1	NBNSR	2 IX
3140	-747DEC23	23:32	265.63	7.8	-8.8	6.0	-3.4	26.3	-16.9	17.7	10.3	44.9	1448546	-747DEC25	17: 5	30	NBNSR	2 X
3141	-746JAN22	10: 3	295.39	3.3	-3.0	3.3	-6.9	22.1	-7.7	16.8	7.3	40.1	1448575	-746JAN23	17:25	30	NBNSR	2 XI
3142	-746FEB20	19:33	324.66	-2.5	1.0	-0.9	-11.3	15.4	-1.0	13.1	2.7	32.7	1448604	-746FEB21	17:49	30	NBNSR	2 XII
3143	-746MAR22	4:22	353.39	9.1	2.6	8.3	-1.9	26.0	1.4	21.8	11.4	42.8	1448633	-746MAR23	18:10	1	NBNSR	2 XIII
3144	-746APR20	13: 5	21.67	3.6	4.2	3.7	-6.4	20.4	2.1	16.5	6.2	36.9	1448663	-746APR21	18:27	30	NBNSR	2 XIV
3145	-746MAY19	22:33	49.71	-1.7	5.3	-0.3	-10.3	14.4	4.1	11.3	0.9	29.6	1448692	-746MAY20	18:45	30	NBNSR	2 XV
3146	-746JUN17	23:29	106.10	8.4	-5.5	7.2	-2.6	16.9	-14.2	14.3	6.1	24.4	1448721	-746JUN19	19: 3	1	NBNSR	2 XVI
3147	-746JUL17	15:40	134.92	6.1	-10.9	6.0	-3.1	12.8	-20.3	11.6	5.5	19.3	1448751	-746JUL19	19: 8	1	NBNSR	2 XVII
3148	-746AUG16	9:27	164.31	4.7	-14.8	4.8	-3.3	11.5	-24.5	10.2	6.1	19.0	1448781	-746AUG18	18:50	1	NBNSR	2 XVIII
3149	-746SEP15	3:30	194.21	6.5	-17.8	5.8	-1.2	15.8	-27.7	12.0	9.7	26.6	1448811	-746SEP17	18:16	1	NBNSR	2 XIX
3150	-746OCT15	20:34	224.44	-1.7	-4.2	-0.2	-10.3	13.7	-12.1	10.7	4.5	28.9	1448841	-746OCT17	17:38	1	NBNSR	2 XX
3151	-746DEC13	11:52	254.70	-1.7	-4.2	-0.2	-10.3	13.7	-12.1	10.7	4.5	28.9	1448871	-746DEC14	17: 1	30	NBNSR	2 XXI
3152	-745JAN12	1: 2	284.70	9.6	-4.6	7.8	-2.3	27.4	-10.2	20.3	11.0	44.8	1448900	-745JAN13	17:16	1	NBNSR	2 XXII
3153	-745FEB10	11:57	314.20	3.4	0.9	3.7	-6.7	21.2	-2.0	17.5	7.2	38.6	1448929	-745FEB11	17:41	30	NBNSR	2 XXIII
3154	-745MAR11	20:52	343.12	-2.7	3.9	-1.1	-11.2	15.0	2.4	13.1	2.8	32.7	1448958	-745MAR12	18: 3	30	NBNSR	2 XXIV
3155	-745APR10	4:27	11.50	10.0	3.7	8.9	-1.3	28.0	1.4	22.7	12.3	45.8	1449017	-745APR11	18:21	1	NBNSR	2 XXV
3156	-745MAY 9	11:39	39.53	5.5	3.4	5.0	-5.1	23.1	-0.8	18.0	7.6	39.5	1449047	-745MAY10	18:38	30	NBNSR	2 XXVI
3157	-745JUN 7	19:39	67.44	0.3	3.2	1.1	-9.1	15.8	-3.5	12.3	2.2	29.4	1449076	-745JUN 8	18:57	30	NBNSR	2 XXVII
3158	-745JUL 7	5:32	95.53	6.5	-4.0	5.7	-4.4	17.1	-12.9	14.2	5.5	26.1	1449105	-745JUL 8	19: 8	1	NBNSR	2 XXVIII
3159	-745AUG 5	18: 4	124.04	6.1	-10.8	5.9	-3.3	13.7	-20.3	12.3	6.2	20.7	1449135	-745AUG 7	18:59	1	NBNSR	2 XXIX
3160	-745SEP 4	9:25	153.13	4.8	-15.2	5.0	-3.0	11.8	-24.6	10.5	6.6	18.9	1449165	-745SEP 6	18:30	1	NBNSR	2 XXX
3161	-745OCT 4	3: 8	182.84	5.8	-17.4	5.5	-1.8	13.9	-26.6	11.3	8.4	23.0	1449195	-745OCT 6	17:52	1	NBNSR	2 XXXI
3162	-745NOV 2	17:16	243.46	1.1	-9.5	1.7	-7.7	11.0	-18.1	8.6	1.6	22.3	1449225	-745NOV 4	17:19	30	NBNSR	2 XXXII
3163	-745DEC 2	17:16	243.46	7.0	-9.5	6.3	-3.1	21.5	-17.2	14.9	7.6	36.2	1449254	-745DEC 4	17: 2	1	NBNSR	2 XXXIII
3164	-744JAN 1	10:38	273.73	2.3	-1.9	2.6	-7.7	17.6	-7.6	13.2	3.6	33.4	1449284	-744JAN 2	17: 8	30	NBNSR	2 XXXIV
3165	-744FEB29	12:35	332.75	3.4	3.7	3.8	-6.4	26.9	-3.9	21.6	11.5	43.2	1449313	-744FEB 1	17:32	1	NBNSR	2 XXXV
3166	-744MAR29	21:23	1.35	-2.6	5.2	-1.1	-11.1	20.1	1.6	17.2	6.8	37.1	1449342	-744MAR 1	17:56	30	NBNSR	2 XXXVI
3167	-744APR28	4:36	29.48	10.5	2.2	8.9	-1.4	14.8	3.1	12.8	2.6	32.7	1449372	-744APR29	18:14	30	NBNSR	2 XXXVII
3168	-744MAY27	11:20	57.37	5.6	0.6	5.0	-5.4	28.7	-1.9	22.6	12.3	45.9	1449401	-744MAY28	18:51	30	NBNSR	2 XXXVIII
3169	-744JUN25	3:32	113.52	3.6	-8.0	3.8	-5.7	13.3	-18.2	11.7	4.8	21.8	1449431	-744JUN26	19: 5	1	NBNSR	2 XXXIX
3170	-744JUL25	14:35	142.25	4.5	-14.7	4.7	-3.5	22.4	-24.4	11.2	7.1	20.1	1449460	-744JUL26	18:43	1	NBNSR	2 XL
3171	-744AUG23	4:35	171.61	6.1	-17.7	5.9	-1.2	14.3	-27.2	12.0	9.5	23.1	1449489	-744AUG25	18: 3	30	NBNSR	2 XLI
3172	-744SEP22	21:31	201.58	1.5	-9.8	2.0	-7.3	10.7	-18.5	8.8	2.0	20.9	1449519	-744SEP24	18: 7	1	NBNSR	2 XLII
3173	-744OCT21	16:52	231.95	7.1	-0.2	5.9	-3.5	18.9	-17.0	13.6	6.2	31.7	1449549	-744OCT23	17:31	30	NBNSR	2 XLIII
3174	-744NOV20	12:55	262.40	1.1	-0.8	1.7	-8.7	14.3	-6.9	10.9	1.2	28.2	1449579	-744NOV22	17: 5	1	NBNSR	2 XLIV
3175	-744DEC20	7:29	292.54	6.2	0.9	5.6	-4.8	20.6	-3.2	16.3	6.1	35.0	1449608	-744DEC21	17:23	1	NBNSR	2 XLV
3176	-743JAN19	10:58	332.75	3.4	3.7	3.8	-6.4	26.9	-3.9	21.6	11.5	43.2	1449638	-743JAN20	17:32	1	NBNSR	2 XLVI
3177	-743FEB18	11:20	57.37	5.6	0.6	5.0	-5.4	28.7	-1.9	22.6	12.3	45.9	1449667	-743FEB19	18:14	30	NBNSR	2 XLVII
3178	-743MAR17	12:35	332.75	3.4	3.7	3.8	-6.4	26.9	-3.9	21.6	11.5	43.2	1449697	-743MAR18	18:21	1	NBNSR	2 XLVIII
3179	-743APR16	11:39	39.53	5.5	3.4	5.0	-5.1	23.1	-0.8	18.0	7.6	39.5	1449726	-743APR17	18:28	30	NBNSR	2 XLIX
3180	-743MAY15	19:39	67.44	0.3	3.2	1.1	-9.1	15.8	-3.5	12.3	2.2	29.4	1449756	-743MAY16	18:35	30	NBNSR	2 L
3181	-743JUN14	5:32	95.53	6.5	-4.0	5.7	-4.4	17.1	-12.9	14.2	5.5	26.1	1449786	-743JUN15	18:42	1	NBNSR	2 I
3182	-743AUG13	9:25	153.13	4.8	-15.2	5.0	-3.0	11.8	-24.6	10.5	6.6	18.9	1449816	-743AUG14	18:49	1	NBNSR	2 II
3183	-743SEP12	3: 8	182.84	5.8	-17.4	5.5	-1.8	13.9	-26.6	11.3	8.4	23.0	1449846	-743SEP13	18:56	1	NBNSR	2 III
3184	-743OCT11	17:16	243.46	7.0	-9.5	6.3	-3.1	21.5	-17.2	14.9	7.6	36.2	1449876	-743OCT12	19: 0	30	NBNSR	2 IV
3185	-743NOV10	12:35	332.75	3.4	3.7	3.8	-6.4	26.9	-3.9	21.6	11.5	43.2	1449906	-743NOV11	19: 0	30	NBNSR	2 V
3186	-743DEC9	11:39	39.53	5.5	3.4	5.0	-5.1	23.1	-0.8	18.0	7.6	39.5	1449936	-743DEC10	19: 0	30	NBNSR	2 VI
3187	-743JAN8	10:38	273.73	2.3	-1.9	2.6	-7.7	17.6	-7.6	13.2	3.6	33.4	1449966	-743JAN9	19: 0	30	NBNSR	2 VII
3188	-743FEB7	12:35	332.75	3.4	3.7	3.8	-6.4	26.9	-3.9	21.6	11.5	43.2	1449996	-743FEB8	19: 0	30	NBNSR	2 VIII
3189	-743MAR6	11:39	39.53	5.5	3.4	5.0	-5.1	23.1	-0.8									